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Application of Critical Chain Project Management to the Production Part Approval Process

David Podolak

APPLICATION OF CRITICAL CHAIN PROJECT MANAGEMENT TO THE PRODUCTION PART APPROVAL PROCESS

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David Podolak

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APPLICATION OF CRITICAL CHAIN PROJECT MANAGEMENT
TO THE PRODUCTION PART APPROVAL PROCESS

Date Recommended 11-11-19

Mark Doggett
Dr. Mark Doggett, Thesis Chair

Dr. Fatemeh Orooji

Dr. Asghar Rezasoltani

Cheryl D. Davis 11/19/19
Dean, The Graduate School Date

This thesis is dedicated to my wife, Annie, whose love and selflessness has allowed me to complete Graduate School and become the father of two amazing children. I also dedicate this thesis to my parents Walter and Linda, who never let me want or feel anything outside of love and encouragement.

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Directed by: Dr. Mark Doggett, Dr. Fatemeh Orooji, and Dr. Asghar Rezasoltani

School of Engineering and Applied Sciences Western Kentucky University

Daicel Safety Systems Americas, INC has traditionally utilized various methods to manage project completions including the Critical Path Method (CPM). Though these methods have led to successful project completions, they often come with adverse effects. Due to the amount of literature and advancement in the project management discipline, alternative options such as Critical Chain Project Management (CCPM) have gained popularity. CCPM seeks to perfect the CPM approach by recognizing resource constraints and the critical chains dependency on them while safeguarding completion dates with buffers. CCPM offers project managers an option to remove resource inefficiency and stalling while meeting deadlines.

The goal of the thesis was to address the validity of CCPM to complete a Production Part Approval Process (PPAP) for a product line addition. The submission was timely due to risk management purposes and manufacturing flexibility. Because of past project history with CPM and the need to advance into a more reliable method, the results of the CCPM approach were heavily analyzed. The project outcome indicated that CCPM offers a viable solution to timely target schedule completions.

Introduction

The automotive industry is tasked with completing thousands of projects during each new model year release. Among these companies are various OEMs, suppliers, and sub suppliers attempting to meet multiple aggressive project timelines. Due to interdependencies and the staggering of projects within tier levels, completions flow upwards until reaching the OEM. Projects within the automotive realm often involve, but are not limited to, line and product validation, internal/external sample testing, and accurate submission of the Production Part Approval Process (PPAP).

The airbag inflator industry deals with the overwhelming time constraints associated with the automotive industry with the added pressure of producing a safety device within vehicles. Inflator performance and sampling are imperative to automotive safety. As expected, the PPAP submission must be completed on time, preferably early, to validate the performance and process. Any delays within the project will directly affect the customer, or module maker, in turn delaying the OEM time requirement.

The PPAP, as defined by Hermans and Yiu (2013), "determine[s] that all customer engineering design record and specification requirements are properly understood by the organization" (p. 41). The validation process is not specific to any single facet, but in fact covers multiple levels of the component during the manufacturing process. Both internal and external organizations that supply either production parts, service parts, production material or even bulk material must meet PPAP requirements (PPAP, 2009). After completion of the PPAP package by an organization, documentation and results are submitted to the customer for review and eventual approval assuming specifications are met.

Requirements for submission are defined in the official PPAP manual. These mandates are listed with more detail in Figure 1. In addition to the defined requirements via PPAP manual, customer specific requirements can also be requested. Examples can include Run at Rates, Problem Follow Up Sheets, audit requirements, and various others. Customers need the PPAP to validate that a manufacturing process can produce consistently and meet requirements at a quoted mass production rate (Hermans & Liu, 2013).

Requirement	Level 1	Level 2	Level 3	Level 4	Level 5
	Submission Level				
1. Design Record	R	S	S	*	R
-for proprietary components/ details	R	R	R	*	R
-for all other components/ details	R	S	S	*	R
2. Engineering Change Documents, if any	R	S	S	*	R
3. Customer Engineering approval, if required	R	R	S	*	R
4. Design FMEA	R	R	S	*	R
5. Process Flow Diagrams	R	R	S	*	R
6. Process FMEA	R	R	S	*	R
7. Control Plan	R	R	S	*	R
8. Measurement System Analysis Studies	R	R	S	*	R
9. Dimensional Results	R	S	S	*	R
10. Material, Performance Test Results	R	S	S	*	R
11. Initial Process Studies	R	R	S	*	R
12. Qualified Laboratory Documentation	R	S	S	*	R
13. Appearance Approval Report (AAR), If applicable	S	S	S	*	R
14. Sample Product	R	S	S	*	R
15. Master Sample	R	R	R	*	R
16. Checking Aids	R	R	R	*	R
17. Records of Compliance With Customer-Specific Requirements	R	R	S	*	R
18. Part Submission Warrant (PSW)	S	S	S	S	R
Bulk Material Checklist (see 4.1 above)	S	S	S	S	R

S= The organization shall submit to the customer and retain a copy of records or documentation items at appropriate locations.

R= The organization shall retain at appropriate locations and make available to the customer upon request.

*= The organization shall retain at appropriate locations and submit to the customer upon request.

Figure 1. PPAP Retention/Submission Requirements. Reprinted from “Section 4 – Submission to Customer – Levels of Evidence,” 2009, *Production Part Approval Process 4th*, p. 18. Copyright 2009 Chrysler Group LLC, Ford Motor Company, General Motors Corporation.

Within Daicel Safety Systems Americas, (DSSA) Inc, the Critical Path Method, along with traditional project management practices is utilized to complete the PPAP in a historically accepted fashion. Though deadlines are often met initially or through recovery, there are outliers that can be improved. As evident and noted within the PMBOK (2013), the CPM calculates early and late completion scenarios without regard for resource limitations or firm scheduling on the assumption that activities will be executed within identified time periods considering logical relationships and constraints. The lack of firm scheduling and use of safe activity durations has led to the delays in projects at DSSA. The need to replace reaction and recovery with on-time results is important for future projects.

There are many alternative methods to CPM. Critical Chain Project Management offers a solution to correct the flaws within that management approach. CCPM, though developed from CPM, considers the effects of resource allocation and availability along the critical path without placing safety margins or extended durations into each scheduled activity (PMBOK, 2013). By following this practice, resources should operate at full efficiency and avoid student syndrome, the outlook that tasks can be completed at the last minute, leading to missed tasks and possible delays. In lieu of safety margins for individual task completions, CCPM does account for limited resources or uncertainties in the form of buffers. A project buffer can be placed at the end of the critical chain path to protect targeted completion while other activity paths can use feeding buffers as they tie into the critical chain (PMBOK, 2013). Since CCPM places more focus on resource constraints and management, the possible benefits from adopting this management discipline are well recognized.

Project Goal

Completion timing is critical to overall success and profitability for any project. The amount of work that goes into managing and tracking projects and insuring their success is often underestimated or misunderstood. Projects encompass activities with interrelationships among one another aiming to produce quality verified deliverables while consuming multiple resources all organized around the competing project constraint (Dinsmore & Cabanis-Brewin, 2011, p. 3-4). Because of all the resource variables associated with projects, DSSA needed to identify new strategies to combat task inefficiencies.

The goal of most organizations for completing a project centers on early completions, spending underbudget, while securing a profit. Though DSSA shares this mindset, there is added pressure for ensuring the quality of a safety device while meeting the requirements and schedules of upper tier suppliers and Original Equipment Manufacturers (OEMs). If PPAPs are submitted late by DSSA, they can cause significant burdens internally as well as a snowball effect for all customers with a stake in the vehicle program.

Project management is an ever changing and evolving discipline practiced in every organization. A project can often fall to last minute completions with damaging consequences. The consequences often include unscheduled overtime, delayed improvements implementations, and other similar occurrences. The goal to avoid these damaging variables associated with project completions has given light to other methods of management at DSSA outside of CPM.

Though CPM is well established inside DSSA and proven in the past, a single lapse raises concern and the need for investigation on a sounder method. Understanding that resources have limitations and factoring those into the management of a project is not only reasonable, but a logical approach. Dinsmore & Cabanis-Brewin noted resource planning issues as "identification and qualification of the resources required; availability of those resources; quantification, or amount, of the resources required; and timing…of the resources" (2011, p. 52). As applied to PPAP items, the accurate and timely allocation of resources is imperative.

Statement of Purpose

The goal of this project will center on the ability of the CCPM to organize and complete a DSSA inflator line addition PPAP package for timely submission to a customer. PPAP regulations and historic customer specific requirements are in place to assess design specifications as needed. Resource allocation and control was well mapped, detailed, and understood prior to starting project activities. Though activities were not padded, applicable buffers were established at points of identified resource limitations or points of uncertainty to coincide with organizational and CCPM directives.

Expected Results

The application of CCPM for PPAP submission was expected to yield desirable results via identified resource constraints and allocated time. The resources needed to complete each phase in the PPAP was allocated based on estimated time constraints and work flow along the critical path and those that feed the critical path. Within any schedule there is expected to be variability. Milestones and tasks prior to PPAP submission were built based on historic results and agreed upon timelines between the DSSA program coordinator and resource departmental management.

Assumptions

The project has the following assumptions:

1. Allocated resources will not terminate employment during the PPAP completion timeline.
2. Customer maintains requested timeline for PPAP submission.
3. Inflator testing on additional line meets customer and drawing specifications.
4. Mass production manufacturing keeps scheduled line time for engineering validation, samples, and delta PV testing.
5. DSSA servers experience no issues and all applications necessary to complete PPAP are accessible when needed.
6. Resource instrumentation and materials, as identified in the Methodology section, operate efficiently and do not break down.
7. No design or drawing changes occur during the inflator additional line PPAP timeline.

Limitations

Engineering validation work and rework for the Delta PV report such as electrical, leak check, etc., was performed on the same line as the inflators were manufactured. The line used was a mass production line, so time was negotiated with the planning department. As possible issues arise such as backorders, poor output, etc., schedules and timing may not align. The Delta PV report is on the critical path within the CCPM diagram because of this timing uncertainty.

Delimitations

The project did not revalidate the design of the inflator. The inflator design, type, and output were an existing program type currently in production for the same customer. The PPAP validated the process and performance of an additional line at DSSA for capacity and risk management purposes. Initial process studies and delta PV requirements were validated because testing specifications insure performance and acceptability of the additional line.

Customer submission requirements are identified in the Methodology section in Figure 5. Any items deemed non-applicable were not submitted for the additional line PPAP. The instruments and materials section discuss items used by individual resources to complete assigned tasks. Though these items are discussed, key metrics are those that track project completion status. The Analysis section details all tasks required for customer submission and breaks down their relationship to the WBS as shown in Appendix A.

Definition of Terms

- BOM: Bill of Materials. List of components used in a finished good.
- CP: Control Plan. Document that defines all methods used for process controls and compliance to customer specific requirements (PPAP, 2009).
- CMM: Coordinate Measuring Machine. Machine used to verify all inflator measurements as specified in the customer drawing.
- Critical Chain: The scheduled path for which the resources are constrained (PMBOK, 2013).

- CCPM: Critical Chain Project Management. Method that allows team to place buffers on any project schedule path to account for limited resources and uncertainties (PMBOK, 2013).
- CPM: Critical Path Method. Method used to estimate minimum duration and determine the amount of schedule flexibility on paths within the schedule model (PMBOK, 2013).
- FB: Feeding Buffer. Buffer that protects the critical chain from feeding chains slippage (PMBOK, 2013).
- Float: Amount of time that a scheduled activity can be delayed or extended from early start date without delaying project finish date (PMBOK, 2013).
- Instron: Machine used to validate weld and crimp maps through destructive testing such as pull, push, torque, shear, etc.
- MSA: Measurement System Analysis. Studies such as gage R&R, bias, linearity, and stability for any modified gages, measurement systems, or test equipment inherent to a process (PPAP, 2009).
- OEM: Original Equipment Manufacturer. As related to project, top level manufacturer using components in vehicle assembly.
- Parkinson’s Law: A law that states work tends to expand and fill the available time (Blackstone, Cox, & Schleier, 2009).
- PF: Process Flow. Diagram or document that defines the production process steps and sequences, as appropriate while meeting customer specific needs, requirements, and expectations (PPAP, 2009).

- PFMEA: Process Failure Mode Effects Analysis. Document that defines the occurrence of any possible failures in a process and assigns rank levels based on the severity of the failure (PPAP, 2009).
- PV: Product Validation. The task of testing a product to ensure it meets the technical specifications and requirements as set by the customer and internal design.
- PPAP: Production Part Approval Process. Determines if design records and specification requirements are understood and met by an organization and that the manufacturing process has the ability to meet those at a quoted production rate (Hermans & Liu, 2013).
- PB: Project Buffer. Buffer placed at the end of the critical chain to protect target finish date from slippage (PMBOK, 2013).
- Student Syndrome: Tendency to put off starting until the last minute (Blackstone, Cox, & Schleier, 2009).
- WBS: Work Breakdown Structure. Breakdown of the total scope of work to be carried out by a project to accomplish objectives and create required deliverables (PMBOK, 2013).

Review of Literature

Multitasking and Multi-Project Environment. All projects require a degree of management and multitasking no matter the size, cost, or schedule involved. In a business or organizational setting, the existence of a single project or task within time does not exist. According to Agarwal and Larson (2014), understanding that even individual projects fail increases the difficulty in a multi-project landscape forcing management to closely track and pay attention to insure all projects success. Project managers also must understand the balance and indicators associated with multitasking while making sure resources complete tasks as quickly as possible. Emsley and Ghaffari (2016) noted that higher or good levels of multitasking should be managed appropriately so they do not damage other facets of the relay race mentality that management needs resources to avoid.

Blackstone, Cox, and Schleier (2009) identified that a “project is comprised of a set of dependent tasks that all must be completed for the project to be completed” and since “some tasks are dependent on others…lateness in one task may delay others” (p. 7029). The actual work inside dependent tasks is completed by the resources applicable for each required skill. Making sure resources are on time and not damaging schedule completion is priority in a multi task based environment. Agarwal and Larson (2014) stated that managers may need help improving the ability to manage projects effectively by concentrating and focusing on those that actually need attention. The effective use of a project management discipline can help identify problems and resource constraints, but managers must also react should the need arise.

Critical Path Method. CPM bases task durations upon agreed safety padding between departments and resources or historical data from prior projects. As noted in the PMBOK (2013), this scheduling technique "calculates the early start, early finish, late start, and late finish dates for all activities without regard for any resource limitations by performing a forward and backward pass analysis through the schedule network" (p. 176). Once all tasks are organized for the project, the longest set of tasks in a sequence are deemed the Critical Path. Blackstone, Cox, and Schleier (2009) acknowledged that the tasks upon the critical path require managerial diligence versus other areas where slack has been identified. Activities along the critical path should be evaluated often to identify possible risks. The example below in Figure 2 shows a completed forward and backward pass CPM schedule model.

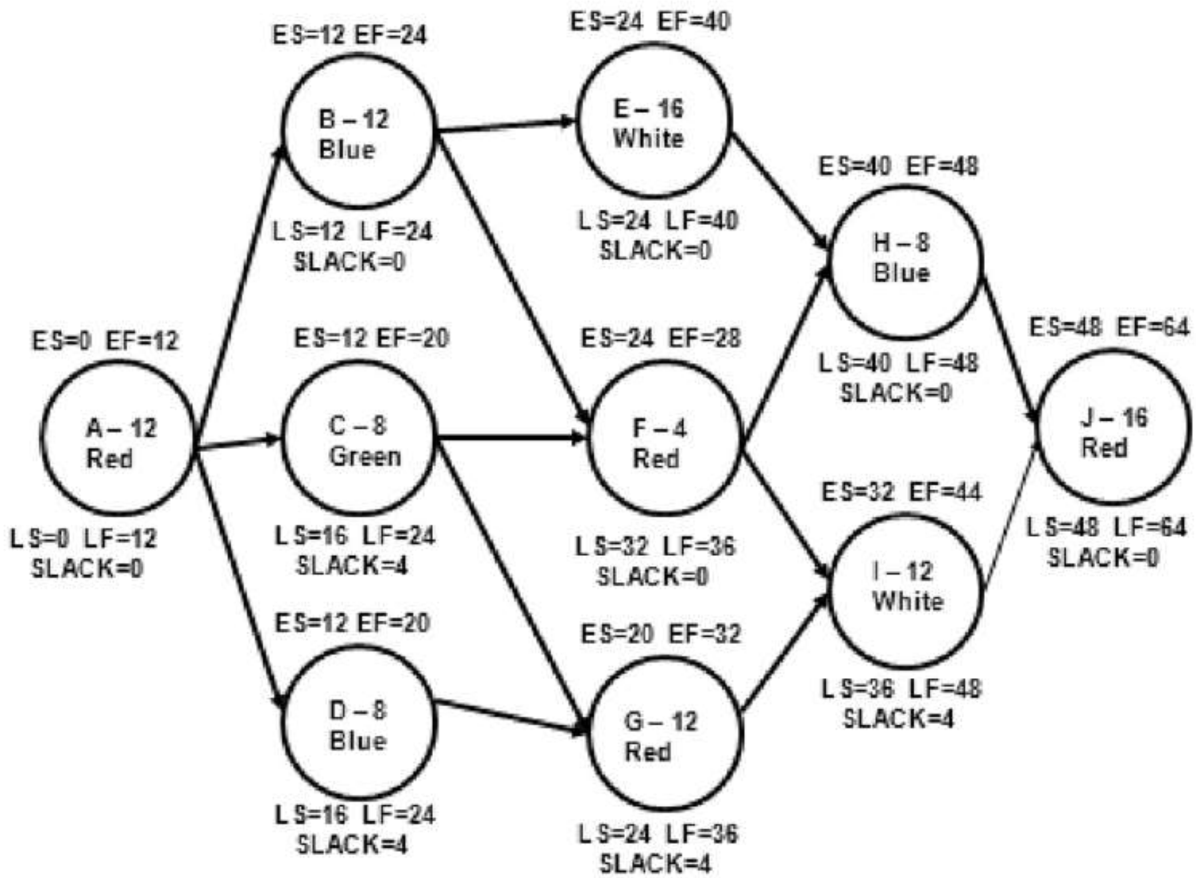

Figure 2. Complete critical path method. Reprinted from "A tutorial on project management from a theory of conservative constraints perspective," by J. Blackstone, J. Cox, and J. Schleier 2009, *International Journal of Production Research 47* (24), p. 7036. Copyright 2009 by Taylor and Francis.

When used properly, the critical path will be easily identified within the CPM model. Beyond longest duration, the critical path is identified by the absence of slack or float between paths. As shown in the PMBOK (2013), total float is calculated as the amount of time that an activity can be delayed or extended along the schedule from an early start date without delaying project completion or violating a constraint. When looking at Figure 2, node sequence ABEHJ have zero slack or float; thus, is identified as the critical path.

Limitations of CPM. A self-defeating factor within CPM according to Blackstone, Cox, and Schleier (2009) is that traditional scheduling revolves around 90% task duration estimates in which the estimator believes there is a 90% chance the task can be completed on time or earlier. These extended or conservative task estimates often lead to poor execution by resources. The adoption of the student syndrome and Parkinson's Law quickly shuts down on time project delivery. These concepts are further detailed below as relatable to task durations.

A calculated float that shows the best and worst case scenario within a project can prove beneficial. Unfortunately, any multitasking or delays by resources inside those constraints can cause damage from inception. Precedent based tasks, as displayed in above Figure 2, are especially susceptible to this phenomenon. As explained by Blackstone, Cox, and Schleier (2009), "If the start of node D is delayed until its LS (16) it will finish on 24; G now cannot start until 24 so it has no slack. Similarly, I can't start until 36 so it has no slack" (p. 7037). In this scenario, a single delayed or late task has devastated the entire CPM model. Anything short of perfection will cause the project to fail the original schedule.

Critical Chain Project Management. CCPM focuses on pushing resources to complete tasks immediately by removing chances for distraction such as student syndrome and Parkinson's Law. According to Blackstone, Cox, and Schleier (2009), CCPM counters student syndrome and Parkinson's Law by using 50% task durations and planning to start each activity immediately after the previous has completed. For a traditional project manager, the leap from CPM practices of 90% task durations are quite substantial. In order to safeguard project completion time, buffers are used in lieu of the slack or float associated with individual tasks in the CPM model. As noted by Emsley and Ghaffari (2016), "One prominent feature of CCPM is replacement of task-embedded safety times, as in the critical path method, with various time buffers including the project buffer, feeding buffer, capacity constrained buffer (CCB), resource buffer and drum buffer" (p. 91).

Using the CCPM method, once the needed buffer time is known, the sequential activities will be scheduled to their latest start date as related to buffer timing. The management portion for the CCPM methodology thus becomes one focused on buffer consumption. According to Emsley and Ghaffari (2016), a new project control system inherent to CCPM promotes the use of buffer management that allows project monitoring through consumption tracking and with visuals such as fever charts. Managers can track project completion status and establish levels of low, moderate, or high concerns as appropriate to amount of buffer consumed in relation to task completion. Project review and status check thus becomes a useful graph representation displaying any concerns with the buffer to project tasks completion ratio.

While the tasks in a project are underway, resources must prescribe to the relay race mentality. As described by Emsley and Ghaffari (2016), resources are to start and complete assigned tasks as soon as possible without regard to the scheduled start or end dates. In addition, resources must remain on a task and complete said task prior to accepting or working on anything else. As stated by Emsley and Ghaffari (2016), resources must focus on 100% dedication to a task until completed as CCP does not allow resources to multitask no matter the circumstance.

Limitations of CCPM. Since the development of CCPM by Goldratt, as discussed in his book ‘Critical Chain’ (1997), many companies have witnessed achievable results by implementing the management system. Unfortunately, the project management system remains younger compared to others in the field. According to Huang and Peng (2014), even though there has been significant research on CCPM, literature on optimization for projects and schedules remains scarce. In addition, most companies have long withstanding project management models that outweigh use of a new system. More often than not, a hybrid or modified model must be used to adapt to the learned behavior or organizational structure of a company.

Resource allocation and management. All projects require the use of resources to complete tasks. Within the literal world, resources are finite and used when and if available. As noted by Pawinski and Sapiecha (2014), the full cost of a resource must be understood and accounted for since each is a single unit applied to different task in sequential order. In terms of most projects, the critical cost in all facets is time. Since time is irreversible, resources must be properly allocated at the start of a project and their task progression tracked throughout.

Though multiple resources can exist within a project, sequential tasks, as identified by the critical chain, are still dependent upon orderly completion. According to Salama, Salah, and Moselhi (2017), “If two or more sequential activities share the same controlling resource, then the priority is given to predecessor activities to respect the continuity constraint of aggressive schedule. Hence, the successor activities start only if there are enough resources to ensure its continuity while logic relationships between preceding and succeeding activities are respected" (p. 34). Task dependency thus prevents working ahead in most instances along the fed critical chain.

The experience level for assigned project resources further impacts completion timelines. As evidenced by Blackstone, Cox, and Schleier (2009), an experienced resource can complete a task more efficiently than an unseasoned resource and their ability to estimate task times is far superior as well. Thus, experienced resources are less likely to guard band their estimated tasks schedules or provide unrealistic completion dates. The experience allows knowledgeable resources to deliver accurately timed completions estimates while inexperienced resources can doom a project with false expectations.

Task duration. Experienced resources and management understand the variables and constraints associated with tasks and how they feed into a project. As stated by Blackstone, Cox, and Schleier (2009), estimating a task "is not an exact science. Tasks are estimated based on subjective estimates of the probabilities associated with factors that might delay the task and resources [that] are accountable for completing the task in that that time" (p. 7030). Duration estimates for CPM and CCPM thus differ greatly in their approach to combat variables via conservative and aggressive targets.

Conservative approaches (90% chance of task completion) within most schedules cause tasks to be viewed as trivial by those involved. With this approach, tasks stand the chance to be ignored until critical. According to Blackstone, Cox, and Schleier (2009), once something goes wrong in a task the built in buffers associated with 90% completion targets will disappear. Because of this phenomenon, tasks will often complete late. The student syndrome effect or last-minute scramble to complete the project is self-defeating because of the known safety net.

Parkinson's Law further affects the willingness of resources to complete tasks on time. In this scenario, work will expand to fill the amount of time allocated for completion. As explained by Blackstone, Cox, and Schleier (2009), resources will allow themselves to multitask with other assignments or procrastinate until the task completes on the prior scheduled date. Any serious problem that arises near the task completion date likely guarantees a late finish.

Establishing an optimum due date or task duration successfully conveys project urgency. According to Blackstone, Cox, and Schleier (2009), a task that is estimated at 50% forces resources to begin work immediately otherwise the task has no chance of finishing on time. Through this process, Parkinson's law, student syndnrome, and early consumption are starved. Organizations that are well established have historical data for project and task completion rates. Simply adjusting estimates based on prior completion rates and adapting to incorporate the above method will bolster resource task completions.

Buffer mechanics. CCPM uses a series of safeguards to account for the scaled back 50% completion task durations. Buffers are established along the project lifespan as they relate to the critical chain or resources. According to Zhao, You, and Zuo (2010), a "feeding buffer (FB) is added to the noncritical activities feeding into the critical chain…the project buffer (PB) is added at the end of the critical chain…and the resource buffer is a flag to alert resources that have been planned on the critical chain…" (p.

1056). FBs are used to prevent noncritical tasks from affecting the critical chain while the PB is used to protect the entire project.

When establishing buffers for a project, an accurate amount of time needs to be applied within each type. According to Lapunka, Pisz, and Wittbrodt (2017), one method, known as BI, involves “setting the path buffer size to half of the sum of the differences between the durations t0.9 (conservative estimates) and t0.5 (aggressive estimates) of the tasks comprising the path” (p. 46). Another method, known as BII, includes “setting the path buffer size to the square root of the sum of squares of the differences between the durations t0.9 and t0.5 of the tasks comprising the path” (p. 46). Both methods of assigning a time span to a buffer allows for a more accurate account versus variable associations.

Buffers are also used to manage and track project progression by monitoring consumption versus project completion rate. As noted by Agarwal and Larson (2014), these measurements indicate if a project is consuming the buffer at a rate proportionate to project completion while providing a visual cue that allows project managers to see areas that need immediate attention. Figure 3 shows a multi project use of the proposed buffer control mechanism.

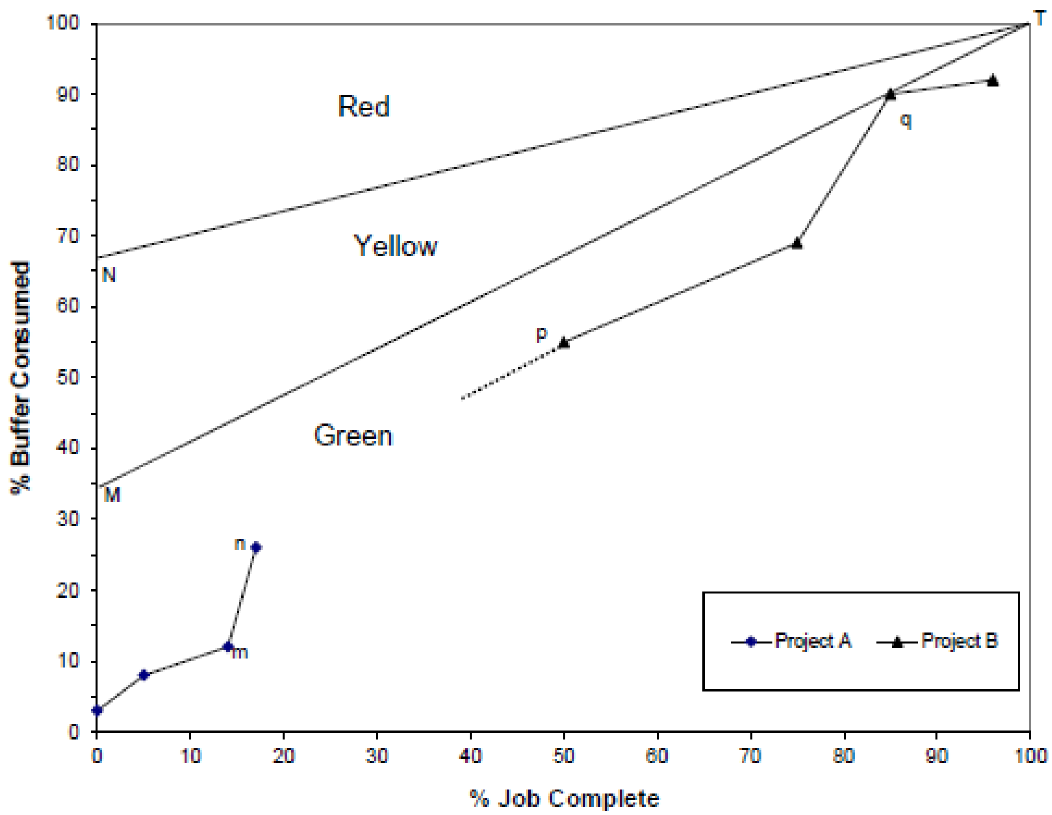

Figure 3. Project Control Mechanic Model. Reprinted from "Mitigating Behavioral Outcomes in a Multi-Project Environment: A Modified CCPM Model," by A. Agarwal and D. Larson, 2014, *Academy of Information and Management Sciences Journal 17,* (2), p. 6. Copyright 2014 by Jordan Whitney Enterprises, Inc.

In the above model, project managers can see rate of progression for a project and identify a potential cause for concern. The axis denotes the percentage use of buffer to project while the green, yellow, and red zones represent areas of no, moderate or high concern. In order to develop the points of concern on the mechanism, Agarwal and Larson (2014) have stated that an organization must determine the maximum acceptable level of consumption of the buffer at 0% project completion that generates no or low concern and high concern respectively. When looking at the above figure, these levels are defined by point M and N as drawn towards point T or the point of 100% consumption. After these points have been established, areas where recovery plans need to be created or implemented become apparent for managers.

Once established, the buffer control graph can be populated with status checks during organizational meetings. In a standard environment with several ongoing projects, reviewing weekly status updates for each X and Y plot on the fever curve provides a detailed visual as apparent in Figure 3. Agarwal and Larson (2014) define these plots "where X = (Total Critical Chain duration – Remaining Critical Chain duration)/(Total Critical Chain duration)*100 and Y = (Buffer consumed/Original scheduled project buffer)*100" (p. 7).

In organizations that have an overwhelming number of projects, additional methods can be used to convey meaningful weekly updates in simple numerical format. Agarwal and Larson (2014) have agreed that in order to determine whether a project is progressing smoothly, weekly data points should be compared by calculating their slope otherwise known as the Buffer Burn Index (BBI). The BBI can be seen below in Figure 4. In accordance with the BBI, a number value above one would denote over buffer consumption while negative numbers would imply gaining back buffer time. Though this method is especially beneficial in a large-scale project atmosphere, it can be just as useful placed alongside a project fever curve.

$$Buffer\ Burn\ Index\ (BBI) = \left(\frac{change\ in\ \%\ buffer\ consumed}{change\ in\ \%\ job\ completed}\right) = \frac{(Y_{current} - Y_{previous})}{(X_{current} - X_{previous})}$$

Figure 4. Buffer Burn Index. Reprinted from "Mitigating Behavioral Outcomes in a Multi-Project Environment: A Modified CCPM Model," by A. Agarwal and D. Larson, 2014, *Academy of Information and Management Sciences Journal 17,* (2), p. 7. Copyright 2014 by Jordan Whitney Enterprises, Inc.

Case Studies. Case studies have helped shed light on the benefits of CCPM versus the CPM. A study by Jyh-Bin Yang used resource leveling in MS-Project software and scenario simulations to distinguish key differences in the completion timeline for a building project. After resource leveling (resource-constrained scheduling), the CPM calculated the project at a 380-day timeline (individual task safety margins) for total and net project durations with over allocated resources on a day-by-day basis (Yang, 2007). CCPM calculated total project duration at 515 days while the net duration (condensed 75% task assurance) held at 356 days (Yang, 2007).

The case study for the building project simulated CCPM scenarios using 75% faster task completions understanding the quick task to task progressions and padding removal. CCPM challenges the CPM as impractical because of built in safety time in each task that leads to student syndrome and observance of Parkinson's law (Yang, 2007). Projects under CCPM are then proved able to meet a condensed scheduled while completing tasks on time versus the CPM.

A hypothetical project for an ad agency also evaluated the use of CCPM versus the CPM for a regional ad campaign. Following standard CPM and resource practices, the project was calculated in Microsoft Project to complete within 29 weeks after the start date (Budd & Cooper, 2004). The raw data used in the study was provided by ad agency executives. The only benefit of CPM (in this instance) was an understanding that successfully coordinating project completion was extremely unlikely without added resources, overtime, and an increased work week up front (Budd & Cooper, 2004).

When applying CCPM to the same study, ProChain was used to implement the management practices into the project. Task times were shortened by 50% and the buffers were composed of half the time removed from tasks allowing for a 21-week project completion scenario (Budd & Cooper, 2004). The reduction in completion time was significant when weighed against the CPM timeframe.

Summary of Literature Review. DSSA projects observe the method and flow of traditional CPM as well as various other disciplines in an attempt to complete projects on time with minimal consequences. As with any project, a larger number of variables interact with the ability of a task and management to ultimately meet with success. Capacity, scheduling, validations, and resource limitations are among the many variables that affect timeline completions. As discussed previously, the primary metrics for a successful project at DSSA include on time or early completions while ensuring a profit. Unfortunately, these metrics are the first that are penalized for a late completion. Resulting countermeasures fall to overtime, outsourcing, missed targets, and customer negotiations.

Traditional thinking and the approach of 90% task durations creates a false safety net that resources often exploit. This behavior is often not blatant, but learned through societal norms and past expectations. Avoidance of resources adopting a student syndrome then becomes a mandate at the start of a project. Therefore, safety durations in each task are removed and any activity that is delayed consumes the feeding or project buffer while forcing resources to avoid Parkinson's Law and student syndrome (Salama, Salah, & Moselhi, 2018). Focusing on 50% task durations for resources is imperative to avoiding overextension.

Through appropriate task duration timing, a critical chain can be developed along with appropriate buffers to counter consumption or missed dates. Implementing CCPM principles is key, but to further ensure success, organizations must track project status through valued metrics. A project fever curve allows for a graphical representation of current project status through a simplex color code for areas of low, moderate or high concern. Additionally, the buffer burn index can provide a quick numerical evaluation for multiple projects and statuses. By using these metrics, anyone can view the current project or task status by looking at the most recent coordinate point (X, Y) that represents the percentage of buffer consumed versus the project completion (Agarwal & Larson, 2014).

Methodology

Procedure

The purpose of this project was to validate the use of CCPM to complete a PPAP package for adding a product to an additional manufacturing line. The project was conducted on site at DSSA in Beaver Dam, Kentucky. All staff members have years of experience in completing tasks that directly feed into customer PPAP packages or those used as supporting evidence. All members have been trained on inflator validation and design as it relates to their appropriate field. In order to ensure project tasks and timelines, an initial kick off meeting established key resource personnel that would report to the program coordinator for duration.

The program coordinator broke down the required PPAP items based on PPAP checklist submitted by the customer as shown in Figure 5. Identified participants, as described following, worked with the program coordinator to establish timelines for completion and tracking progress. Initial task times were generated based on agreement of a 90% chance of completion by the program coordinator, resources, and managers of the selected resource. After the initial task times were established, the program coordinator and resource managers scaled back completion estimate times to 50%.

Resources were informed that the scaled 50% task completion estimates were established as key milestones in order to submit the PPAP on time to the customer. The line addition was of immediate need due to future program volume increases and the need for improved line balancing for inflator type. In addition, the early submission date would compensate for the standard delay in processing time associated for non-critical change requests at the customer and any required testing. Resources were instructed to work as fast as possible in order to meet or even exceed scaled task milestones when possible. In addition, resources were required to avoid multitasking with any work outside the project until they completed their sequential role. The program coordinator was responsible for organizing and reviewing final departmental documentation and data for PPAP submission in compliance with customer requirements as detailed in Figure 5.

TOYODA GOSEI

FORD - PPAP Checklist

Program: [redacted]

Part Description: LE2-120 KAB Inflator

Part No: [redacted]

	Included in PPAP? Indicate below with an X.		
	Yes	No	Comments
1. Design Records	X		Drawings
2. Authorized Engineering Change Documents	X		Revision for S4 Line Addition
3. Customer Engineering Approval	X		S4 Delta PV Agreement
4. Design FMEA		X	N/A
5. Process Flow Diagram	X		Additional S4 Line
6. Process FMEA	X		Additional S4 Line
7. Control Plan	X		Additional S4 Line
8. Measurement System Analysis Studies	X		Additional S4 Line
9. Dimensional Results	X		n=6 S4 Line
10. Records of Material / Performance Test Results	X		LAT data, S4 Delta PV
11. Initial Process Studies	X		S4 Line Data
12. Qualified Laboratory Documentation	X		Required
13. Appearance Approval Report (AAR)		X	N/A
14. Sample Production Parts	X		n=6
15. Master Sample	X		Retain
16. Checking Aids	X		S4 Line
17. Customer Specific Requirements	X		
A. E-108 Brand Compliance		X	N/A
B. Heat Treatment Assessment		X	N/A
C. Reporting, Identification and Marking of Materials		X	N/A
D. PD Approval of PV Tests	X		S4 Line Delta PV
E. SCCAF Form	X		S4 Line Data
F. Pass-Through Characteristics (PTC)		X	
G. MSA ANOVA Method	X		S4 Line Data
H. Sub-Supplier PSW's		X	No Change
I. Shipping Label		X	N/A
J. Critical Parameters (Molding, Plating)		X	N/A
K. Ford Property Tag - Tooling		X	N/A
L. CQI-15	X		S4 Line
M. Contingency Plan		X	Submitted in Original PPAP
18. PPAP Part Submission Warrant (PSW)	X		Submit

Figure 5. Customer required PPAP submission items for S4 line addition.

Participants

Resources for this project spanned several departments as with typical PPAP completions at DSSA. Key members for organizing the data for PPAP submission include prelaunch specialists and the program coordinator. Table 1 breaks down official titles of each participant as relatable to their department. From the quality group, eight members were used to support PPAP items and completion. Additional members included four from engineering, one from the technical center, and one program coordinator. Official members and their responsibility for supporting timely completion for the PPAP were set March 14th, 2019.

Table 1

Resource Identification and Coding

Department	Title	Resource Code
1. Quality Member	Assistant Quality Manager	Green
2. Quality Member	Quality Engineer	Blue
3. Quality Member	Prelaunch Supervisor	Red
4. Quality Member	Prelaunch Specialist	Red
5. Quality Member	Prelaunch Specialist	Red
6. Quality Member	Calibration Technician	Grey
7. Quality Member	Calibration Technician	Grey
8. Quality Member	LAT Lab Specialist	Black
9. Engineering	Process Engineering Leader	Yellow
10. Engineering	Process Engineering Specialist	Yellow
11. Engineering	Process Engineering Specialist	Yellow
12. Engineering	Process Engineer	Yellow
13. Technical Center	Senior Technical Engineer	Orange
14. Project Management	Program Coordinator	Purple

Note. Resource color code applied for visual benefit on the WBS.

Instrumentation and Materials

The PPAP required items were generated based on the applicable customer submitted PPAP checklist. A WBS was developed from the PPAP checklist to better understand its relation to individual tasks shown in Table 1. The WBS also helped to better display the task interdependencies. Each task was color coded to coincide with applicable resources as defined in the participant section. The items due were weighted in the project through a series of metrics for allocating task time durations and tracking project status through buffer consumption. The WBS is shown in Figure 6.

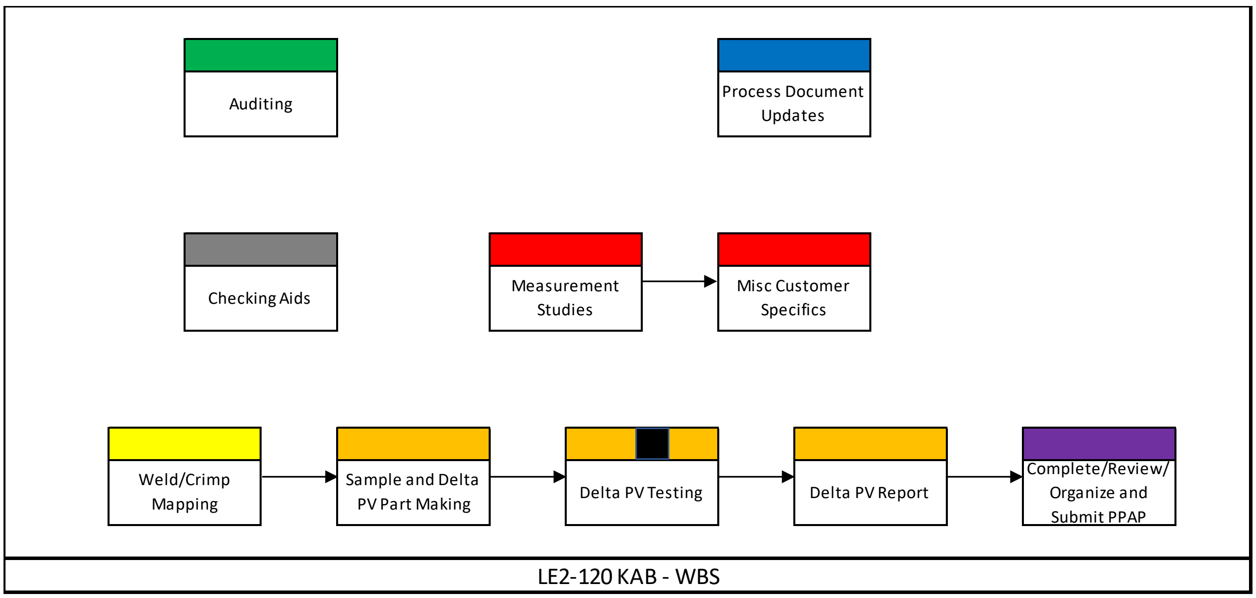

Figure 6. WBS for resource to task identification.

A simple formula was used to scale back individual task times from the estimated 90% completion rates to desired 50% rate. In the formula, TT represents task time while x represents the agreed 90% completion time between all parties. The last two interactions involved the time scaling percentages displayed as t0.9 or t0.5 respectively. The formula is visualized as TT=(x/t0.9)t0.5.

The BI method, as discussed in the literature review, was used to calculate the appropriate amount of time to place in the feeding and project buffers. These calculations are detailed in the analysis section. As referenced above, the modified project management buffer consumption metric (i.e. Project Fever Chart) and BBI were applied to monitor project status. These tools were facilitated in Excel and helped ensure that buffer consumption was at a safe level when compared to project task completions. Weekly meetings were used to track project status and update project fever chart. The areas of low and high concern as well as the tracking graph used are detailed in the next section.

As discussed in the delimitations, resources used several in-house standards, software, and hardware to gather the submission items. DSSA inflator drawing was used for ballistic output and dimensional tolerances. Daicel Technical Standards (DTS) were used to validate all weld and crimp characteristics within the inflator as well the tuning for output. AutoDCP software currently used on existing Process Flow (PF), Control Plan (CP), and Process Failure Mode Effects Analysis (PFMEA) was used for purpose of applicable updates. In-house Keyence Coordinate Measuring Machine (CMM) and Instron machines were used for dimensional and tolerance data collection associated with capability studies. Minitab and Excel were also used to collect and study data as part of the Measurement System Analysis (MSA), initial capability studies, and schedule tracking.

Threats to Validity

The threat to the validity of the project thesis lies within the resource members selected and the learned culture at DSSA. Though PPAPs, new programs, and process changes are a constant at DSSA, what members understand as an acceptable schedule to complete a project has been based on historic 90% completion ratio or above. Members are familiar with last second emergency completions within a shortened timeframe, but applying a 50% completion rate for tasks upfront in a planned out PPAP submission was a first-time occurrence.

The avoidance of the fight or flight mentality was key in keeping resources at ease and focused on task completion versus missed completion target rationale. To counter this mentality, the program coordinator, resources and departmental managers selected task schedules based on 90% chance for successful completion. As reinforced by Blackstone and Cox (2008), "[t]o maintain morale it is important to communicate to workers that management understands that even with a best effort the task will run long 50% of the time" (p. 7039).

In order to keep resources focused on 50% completion times and due date as discussed above, each member was informed that tasks as related to the on-time PPAP submission would be one of the Key Performance Indicators (KPI) for 2019. KPIs directly reflect annual raises and bonuses within DSSA for all team members. Each resource was also requested to share any concerns for on-time completion with the program coordinator when identified (even if outside of scheduled weekly meetings) such as outside requests for multitasking, slippage, or any other occurrences.

Lastly, resources were informed of task planned end dates as milestones within the project. Milestones were used as reference points off the generated close dates inside the project fever chart timelines due to the cultural background and learned mentality at DSSA for having actual scheduled due dates. Resources were informed to work as fast as possible sequentially without multitasking and close prior to any milestone approach as these were tracking metrics of the project for managerial purposes only. The buffers and other facets in the schedule were shared with all members of management for reference on the entire span of the project.

Approach

On March 15th, 2019, the program coordinator met with the selected resources from the March 14th kickoff meeting. Each resource type met one-at-a-time with the project coordinator and applicable departmental manager. After agreeing upon a 90% completion time between all parties, each task was scaled to 50% using TT=(x/t0.9)t0.5. The WBS was modified to reflect the 90% and 50% completion times as shown in the Appendix A along with minor updates from prior revisions. In addition, a timeline was added for scale to reference the 50% CCPM approach with buffer. Historical completion times from prior CPM based projects and PPAPs were used as points of reference during the 90% on-time selection along with resource determination. For each task, the appropriate time was rounded to the nearest whole day. Weeks and months were based on standard 40-hour work weeks (i.e. 5 days in a week and 20 days in a month). Scheduled company holidays were factored into the schedule.

After completing the 50% scaling, the program coordinator was able to identify the appropriate size of the feeding and project buffer using the BI method. The calculations for the buffer sizing are shown in Figure 7. The feeding buffer was based on the longest task series that fed into the critical chain. In addition, the WBS was updated to reflect the calculated amount of both buffer types and reflected in schedule. The buffer is referenced in pink with the WBS in Appendix A.

Feeding Buffer
BI = 1/2 ((t0.9[conservative estimates]) - (t0.5[aggressive estimates]))
BI = 1/2 ((2weeks + 2weeks) - (1.2weeks + 1.2weeks))
BI = 1/2 ((1month) - (2.4weeks))
BI = 1/2 (1.6weeks)
BI = 4 days

Project Buffer
BI = 1/2 ((t0.9[conservative estimates]) - (t0.5[aggressive estimates]))
BI = 1/2 ((3.5months + 4days + 1.25months + 1week + 2weeks) - (1month 3.8weeks + 2days + 2.8weeks + 3days + 1.2 weeks))
BI = 1/2 ((5.5months 4days) - (3months 1week))
BI = 1/2 (2months 1.8weeks)
BI = 1.25 months

Figure 7. Calculation for buffer size based on BI method.

Specific task planned start and end dates for the project fever curve were decided based of the 50% completion rate as shown in Figure 8. These dates were established to feed into the BBI calculation along with any slippage or buffer consumption. During each weekly meeting, completion percentage and days remaining for each task milestone was updated by assigned resources. Any resources that completed a task ahead of schedule were required to meet with the program coordinator immediately. The program coordinator was responsible for informing the next sequential resource to begin working on assigned task if another task completed outside of weekly scheduled meetings. In addition, any resources or the program coordinator could request a meeting for emergency concern items as needed throughout the project duration.

Task-ID	Task Description	Typ	CC	Current Start	Current End	Planed Start	Planed End
10	Weld & Crimp Maps		CC			6/6/2019	8/1/2019
11	Checking Aids					8/2/2019	8/9/2019
12	Line Auditing					8/2/2019	8/6/2019
20	Delta PV and Sample Making		CC			8/2/2019	8/5/2019
21	Measurement Studies					8/6/2019	8/13/2019
30	Delta PV Testing		CC			8/6/2019	8/23/2019
31	Process Document Updates					8/14/2019	8/21/2019
32	Customer Specifics					8/14/2019	8/16/2019
40	Delta PV Report		CC			8/26/2019	8/28/2019
50	Organize, Review and Submit PPAP Package		CC			8/29/2019	9/6/2019

Figure 8. Schedule for planned task time start and end dates.

The project fever curve was setup to reflect zones of low or little concern (M) at 20% buffer consumed for the project. Point of medium or large concern (N) was set at 50% buffer consumed for the project. Figure 9 shows the template for the project fever curve that was used during the PPAP completion process. The program coordinator set more conservative levels for the yellow portion of chart since this was the first application of CCPM at DSSA. This allowed for concern points to come into view quickly versus the percentages discussed in the literature review section. Project status was reviewed at weekly meetings on Tuesday (pending resource availability) and the fever curve was also updated after each meeting in case a recovery plan needed to be created. As discussed prior, the emergency meetings would also be a point of update for the project fever curve should they be needed.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019					
6/18/2019					
6/25/2019					
7/2/2019					
7/9/2019					
7/16/2019					
7/23/2019					
7/30/2019					
8/6/2019					
8/13/2019					
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

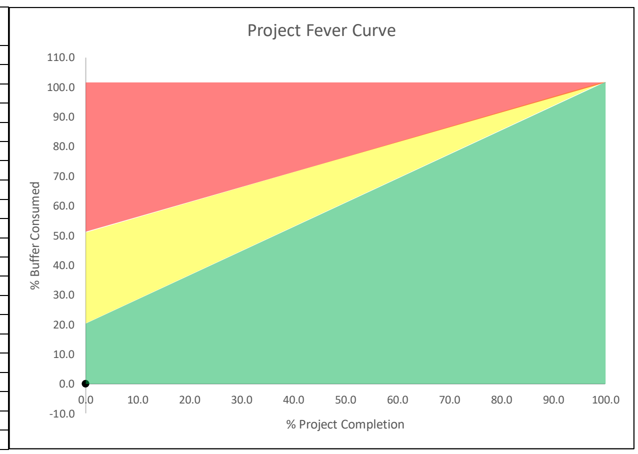

Figure 9. Project Fever Curve template without data points.

The data for the project fever curve was calculated as detailed in the Literature Review, specifically how to determine X and Y plots. Table 2 shown below is the template for reference points discussed in this section. These methods and below explanations where applied to all points of calculation in the project and tables represented in the findings section.

The timeline is reflective of the date during which each meeting took place. CC Duration – Actual (Percentage) represented the amount of the project left to complete. Once this zeroed out, the project would be complete. The % Job Complete and % Buffer Consumed represented the current status on a given meeting and was used to calculate the BBI as well as plot points on the project fever curve. The color-coded section tied the % Job Complete with the current task and showed the same data as a visual benefit.

Task Percentage was based off resource reported completion status for any given meeting date. As each task accounted for a percentage of the overall project (critical chain or feeding buffer), Task Percentage was scaled down to reflect the color-coded sections overall project relation. For example, if engineering stated they where 10% complete on June 6th, overall project completion would sit a 6% respectively. Lastly, Completion Project Target Percentage is the percentage at which completion should be on a give date assuming a 100% completion on September 6th, as discussed with resources.

Table 2

Example of the Calculation Template for Project Task Status

CC Duration 65 Days Project Buffer Duration 25 Days	
Timeline	6/6/2019
CC Duration - Actual (Percentage)	100.0
% Job Complete (X)	0.0
% Buffer Consumed (Y)	0.00
Completion Project Target Percentage	0.00
Weld/Crimp - 60% of Project	0.00
Task Percentage	0.00

Note. Zeroed out to reflect status at official project start on 6/6/2019.

Findings

Week One and Two

The project officially started on June 6th, 2019 and the first weekly meeting occurred on June 11th, 2019. Results of initial meeting are displayed in Figure 10. Engineering was able to complete a large amount of the weld study when compared to the weeks target percentage as shown below in Table 3. In turn, the project was able to start out with -7.4% consumption to the project buffer which helped to support the critical chain safety margin.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019					
6/25/2019					
7/2/2019					
7/9/2019					
7/16/2019					
7/23/2019					
7/30/2019					
8/6/2019					
8/13/2019					
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
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9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

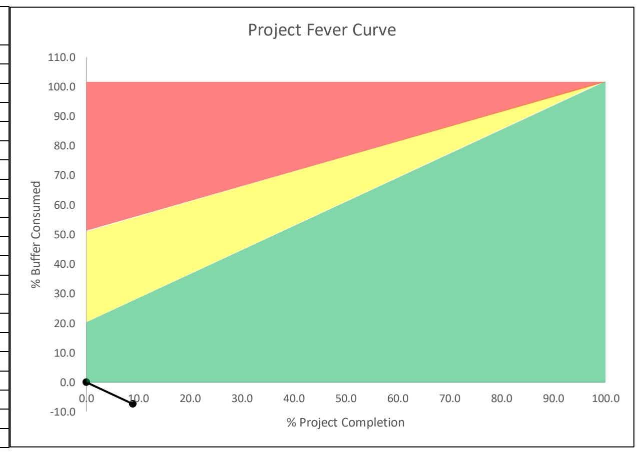


Figure 10. Project Fever Curve 6/11/2019.

Table 3

CC Task to Project Status and Completion vs Consumption – Weld and Crimp

CC Duration 65 Days Project Buffer Duration 25 Days	
Timeline	6/11/2019
CC Duration - Actual (Percentage)	91.0
% Job Complete (X)	9.0
% Buffer Consumed (Y)	-7.39
Complete Project Target Percentage	6.16
Weld/Crimp - 60% of Project (Actual)	9.00
Task Percentage Complete	15.00

Note. Project actual section reflects the how task completion status feeds into the overall project. The yellow highlight section coincides with the WBS departmental color code.

The second week of the project continued to advance the completion favorably. During the weekly meeting, no points of concern were identified. Some of the additional buffer gained from the previous week were consumed as shown in Table 4. Since the BBI was positive, the fever curve in Figure 11 did move in relation to project status change, but not enough to break into the unused project buffer. At this point in the project, engineering completed 25% of their task reflecting 15% overall project completion.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019					
7/2/2019					
7/9/2019					
7/16/2019					
7/23/2019					
7/30/2019					
8/6/2019					
8/13/2019					
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

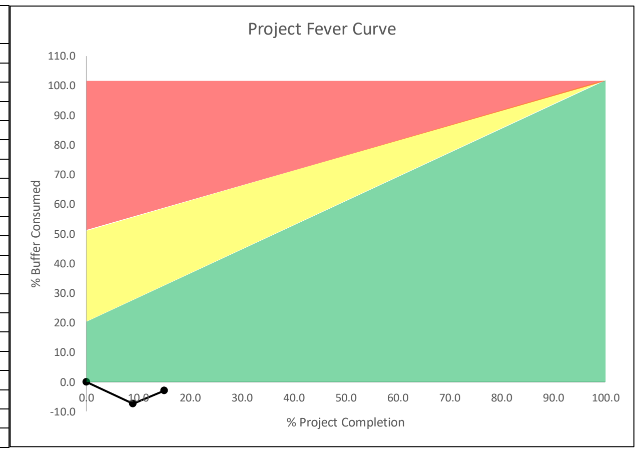


Figure 11. Project Fever Curve 6/18/2019.

Table 4

CC Task to Project Status and Completion vs Consumption – Weld and Crimp

CC Duration 65 Days Project Buffer Duration 25 Days		
Timeline	6/11/2019	6/18/2019
CC Duration - Actual (Percentage)	91.0	85.0
% Job Complete (X)	9.0	15.0
% Buffer Consumed (Y)	-7.39	-2.98
Complete Project Target Percentage	6.16	13.85
Weld/Crimp - 60% of Project (Actual)	9.00	15.00
Task Percentage Complete	15.00	25.00

Note. Meeting 6/19/2019 calculations.

Week Three

On the third weekly meeting, the first instance of positive buffer consumption occurred. Though week two had consumed buffer as well, the prior week's surplus buffer still covered the increased consumption. The 1.6 BBI (as show in Appendix B) accounted for this increase and the swing from the percentage buffer consumed of -3.0% to 4.5% was evident. When this data was plotted in the Fever Curve, it became a clear changepoint. The Week 3 table in Appendix B shows updated calculation for critical chain task to project overall status. Actual task completion for week three of 19.80% fell short of the 21.55% target completion.

During week three, the program coordinator was informed of a possible drawing and component change for this inflator by the customer and DSSA design. In addition to the PPAP project validating the line addition, it would also have to validate the possible changepoints. Changepoints were minimal, but did affect two components and an angle clocking for harness retention. As two of the items would need component level PPAPs, supplier development was immediately informed to request component PPAPs in case of a drawing change and future release. Until the change was confirmed, the item would not be added to the overall project scope. The harness orientation was not of significant concern as this was controlled in the manufacturing line settings.

Week Four

At this point in the project, an upward trend was starting to develop as shown in Figure 12 (BBI of 2.2). Though this trend was not within the area of concern on the Project Fever Curve, the program coordinator still elected to discuss the point of concern with engineering and the departmental manager. Engineering members conveyed that supplier development had been requesting weld work to validate the equivalency of a supplier for a component outside the scope of the additional line project (or the possible changepoint discussed in week 3).

The program coordinator met with supplier development members and engineering staff to reiterate the project importance and current status as shown in Figure 12. After explaining that the engineering members target to complete all items fell between week 8 and 9 as shown in Figure 8 (initial planned start and end dates), all members agreed to push forward and attempt to make up the consumed buffer and complete the task on time. The target time allowed for supplier development to still meet their timeline assuming timely completion of the task and reduction to the current 13.6% buffer consumption as shown in Table 5.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019					
7/16/2019					
7/23/2019					
7/30/2019					
8/6/2019					
8/13/2019					
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

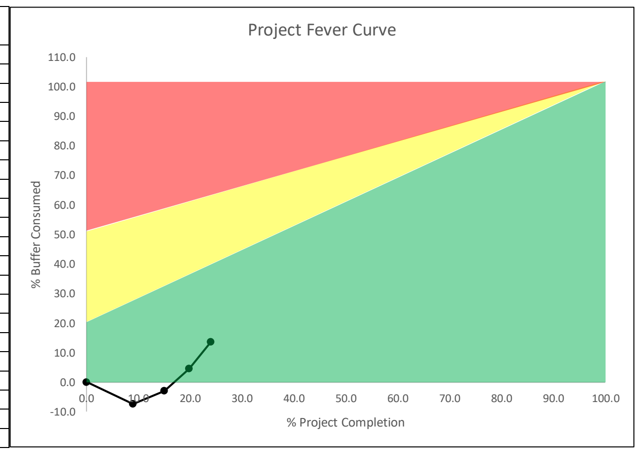


Figure 12. Project Fever Curve 7/2/2019.

Table 5

Task to Project Status and Completion vs Consumption – Weld and Crimp

CC Duration 65 Days Project Buffer Duration 25 Days				
Timeline	6/11/2019	6/18/2019	6/25/2019	7/2/2019
CC Duration - Actual (Percentage)	91.0	85.0	80.2	76.0
% Job Complete (X)	9.0	15.0	19.8	24.0
% Buffer Consumed (Y)	-7.39	-2.98	4.54	13.61
Complete Project Target Percentage	6.16	13.85	21.55	29.24
Weld/Crimp - 60% of Project (Actual)	9.00	15.00	19.80	24.00
Task Percentage Complete	15.00	25.00	33.00	40.00

Note. Meeting 7/2/2019 calculations.

Week Five - Seven

During week 5 and 6, the project had favorable improvement along the timeline. Engineering was able to reclaim all the consumed buffer in week five as shown in Figure 13 and Table 6. During week six, significant task completion for weld and crimp work continued (as shown in Appendix B). Though week seven did have some buffer consumption (7.24%), it was deemed insignificant because of the prior underconsumption or reclamation of the buffer in weeks five and six. Appendix B shows the current status for project completion at 48% after week seven.

The drawing and component changes were also confirmed during week seven and discussed during the project status meeting. Supplier development currently had a full PPAP in house for both parts since the original week three request. Supplier development confirmed that the PPAP for components were complete without issue. Before a warrant could be signed, DSSA had to receive the official top-level drawing and bill of materials. As these items are issued from Japan, DSSA had to wait for official drawing and BOM release. Pending drawing release timing, the sample and delta PV build could also be delayed in later weeks.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019					
7/23/2019					
7/30/2019					
8/6/2019					
8/13/2019					
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

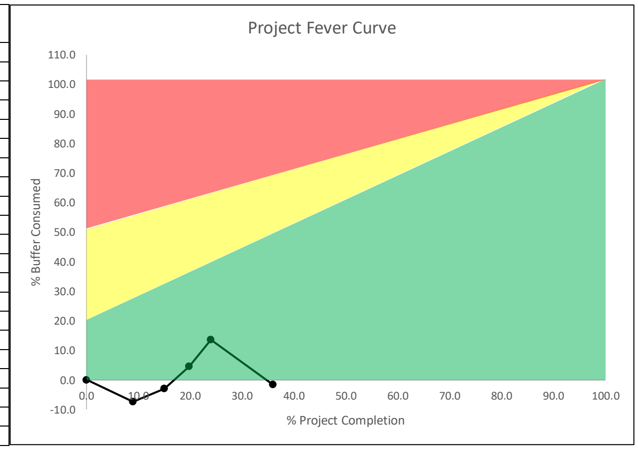


Figure 13. Project Fever Curve 7/9/2019.

Table 6

Task to Project Status and Completion vs Consumption – Weld and Crimp

CC Duration 65 Days Project Buffer Duration 25 Days					
Timeline	6/11/2019	6/18/2019	6/25/2019	7/2/2019	7/9/2019
CC Duration - Actual (Percentage)	91.0	85.0	80.2	76.0	64.0
% Job Complete (X)	9.0	15.0	19.8	24.0	36.0
% Buffer Consumed (Y)	-7.39	-2.98	4.54	13.61	-1.57
Complete Project Target Percentage	6.16	13.85	21.55	29.24	35.40
Weld/Crimp - 60% of Project (Actual)	9.00	15.00	19.80	24.00	36.00
Task Percentage Complete	15.00	25.00	33.00	40.00	60.00

Note. Meeting 7/9/2019 calculations.

Week Eight and Nine

During the week eight meeting, the program coordinator was informed that the weld and crimp task would not be able to close out until the following week. Though the work would likely complete on the 1st or 2nd, DSSA must have all weld and crimp maps go through a final review and approval in Japan in addition to local plant approval. As of 7/30/2019 meeting, overall project completion was at 57% as shown in Section 4 of Appendix B. The target to receive Japan approval was set for the next weekly meeting on 8/6/2019. The delay also affected the non-critical chain tasks (checking aids and auditing) start times.

Japan approval was received on week nine and reviewed during the weekly status meeting. Though task completion for engineering had closed as 60% of the entire project, the buffer had been consumed by 16.1% as noted in Figure 14 and Table 7. In addition, DSSA had still not received the official top-level drawing or BOM due to ongoing discussion and negotiations in Japan. Because of this issue, DSSA would be only able to produce the subassembly portion of the inflator as only the subassembly drawing was correct to that level. The subassembly build was scheduled to complete by the next status meeting as DSSA was informed the top-level drawing target approval for design and customer was roughly two to three weeks.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019	60.0	16.1	3.0	12.2	4.1
8/13/2019					
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

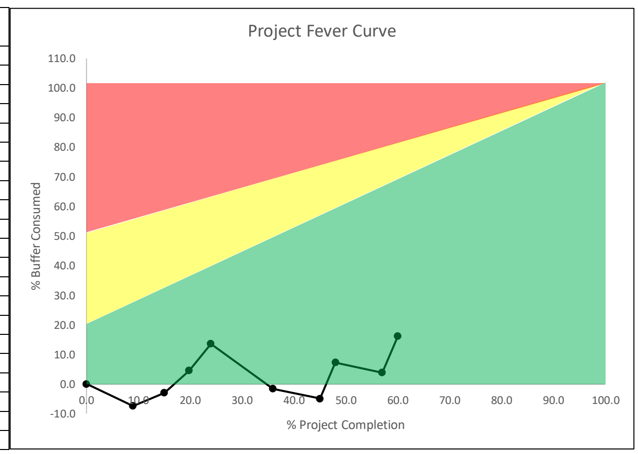


Figure 14. Project Fever Curve 8/6/2019.

Table 7

Task to Project Status and Completion vs Consumption – Weld and Crimp

CC Duration 65 Days Project Buffer Duration 25 Days									
Timeline	6/11/2019	6/18/2019	6/25/2019	7/2/2019	7/9/2019	7/16/2019	7/23/2019	7/30/2019	8/6/2019
CC Duration - Actual (Percentage)	91.0	85.0	80.2	76.0	64.0	55.0	52.0	43.0	40.0
% Job Complete (X)	9.0	15.0	19.8	24.0	36.0	45.0	48.0	57.0	60.0
% Buffer Consumed (Y)	-7.39	-2.98	4.54	13.61	-1.57	-4.95	7.24	3.86	16.05
Complete Project Target Percentage	6.16	13.85	21.55	29.24	35.40	43.09	50.79	58.49	66.18
Weld/Crimp - 60% of Project (Actual)	9.00	15.00	19.80	24.00	36.00	45.00	48.00	57.00	60.00
Task Percentage Complete	15.00	25.00	33.00	40.00	60.00	75.00	80.00	95.00	100.00

Note. Meeting 8/6/2019 calculations.

The first series of non-critical chain tasks also were launched during the week nine meeting. Since the weld and crimp maps were approved, the checking aids and auditing process was approved to begin. Status was set at zero for 8/6/2019 and scheduled forward from that point due to the delay in the weld and crimp task completion. Section 1 in Appendix C displays the non-critical chain tracking status for this portion of the project. Because of the known drawing delay and gap between the other future non-critical tasks that formed the feeding buffer, these tasks did not account for consumption.

Week Ten

On the tenth week of the project, the sub assembly portion for the delta PV build completed. Unfortunately, the delay in the drawing and BOM release caused significant buffer consumption and significant approach to the yellow graph portion as shown in Figure 15. As noted in Table 8, the buffer consumption now rested at 32.15%. That increase represented roughly double since week nine status check. The non-critical task as displayed in Section 1 of Appendix C completed ahead of schedule and was removed from the project tracking.

The program coordinator was informed on week ten that the top level drawing and BOM would officially release no later that 8/27/2019 in order to support the initial project and current identified change points. In addition, the customer was now required to be present during the top level (finished goods) build to observe the line for any points of concern. The program coordinator met with the technical engineer and production planner to schedule official build timing for the mainline (top level). At the request of the customer and availability of planning, the mainline build was scheduled for 8/29/2019.

During the week ten review meeting all these points of concern were discussed with the current and remaining departments that had open or queued tasks. Although tasks had already been moved to 50% aggressive estimates, all members were informed that unless those estimates were beaten the project would ultimately miss the required submission date. The technical engineer accounted for the majority of task percentage remaining in the critical chain. As there was now two weeks of queue time until the drawing release and scheduled mainline build, the technical engineer was required to close any items that would impede full devotion to the task or cause any concerns during the scheduled delta PV testing timeline immediately.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019	60.0	16.1	3.0	12.2	4.1
8/13/2019	61.5	32.1	1.5	16.1	10.7
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

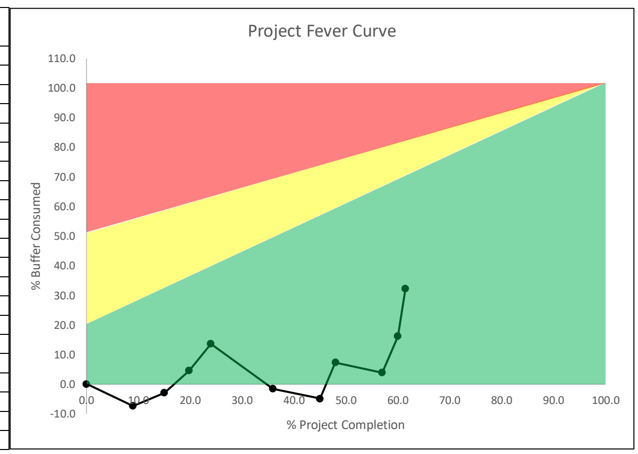


Figure 15. Project Fever Curve 8/13/2019.

Table 8

Task to Project Status and Completion vs Consumption – Delta PV and Sample Making.

CC Duration 65 Days Project Buffer Duration 25 Days	
Timeline	8/13/2019
CC Duration - Actual (Percentage)	38.5
% Job Complete (X)	61.5
% Buffer Consumed (Y)	32.15
Complete Project Target Percentage	73.88
Sample / DPV Parts - 3% of Project (Actual)	61.50
Task Percentage Complete	50.00

Note. The section is highlighted orange to coincide with the WBS departmental colors. Meeting 8/13/2019 calculations.

Week Eleven and Twelve

As discussed during the week ten review, weeks eleven and twelve had very minimal impact to project completion percentage. The technical engineer was able to make small progression such as internal prep work and component staging in preparation of the build date. Figure 16 and Table 9 show the damaging effects of the lapse in project completion during week eleven. The buffer percentage consumed rose to 51.5% and the BBI had the highest shown value since inception (77.4). Week twelve contributed similar results with the buffer consumption percentage now sitting at 70.8% as displayed in Table 10 below. Week twelve also entered the yellow zone of concern in Figure 17 for the first time in the project schedule. The week twelve meeting reiterated the points discussed in week ten for missed submission date concerns.

The official drawing and BOM was received on 8/27/2019 allowing for top level manufacturing of inflator. In addition, supplier development was able to review and sign off on component PPAPs due to official receipt for drawings and BOM. These actions ensured the prior scheduled build for 8/29/2019 with planning and the customer. An additional follow meeting was scheduled for 8/29/2019 after completion of the sample and delta PV build to launch the next tasks and emphasize completion timing.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019	60.0	16.1	3.0	12.2	4.1
8/13/2019	61.5	32.1	1.5	16.1	10.7
8/20/2019	61.8	51.5	0.3	19.3	77.4
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

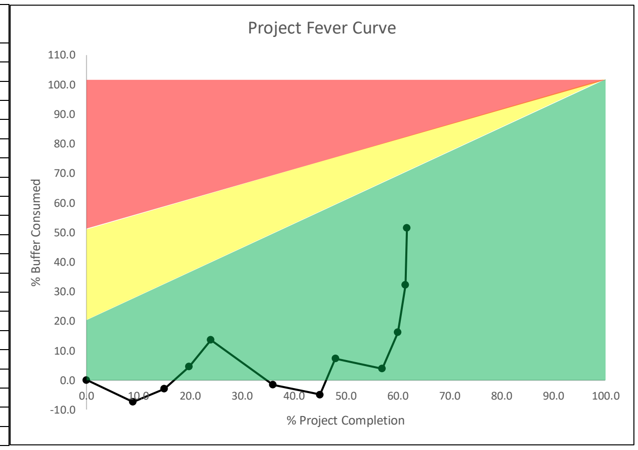


Figure 16. Project Fever Curve 8/20/2019.

Table 9

Task to Project Status and Completion vs Consumption – Delta PV and Sample Making.

CC Duration 65 Days Project Buffer Duration 25 Days		
Timeline	8/13/2019	8/20/2019
CC Duration - Actual (Percentage)	38.5	38.3
% Job Complete (X)	61.5	61.8
% Buffer Consumed (Y)	32.15	51.49
Complete Project Target Percentage	73.88	81.57
Sample / DPV Parts - 3% of Project (Actual)	61.50	61.75
Task Percentage Complete	50.00	58.00

Note. Meeting 8/20/2019 calculations.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019	60.0	16.1	3.0	12.2	4.1
8/13/2019	61.5	32.1	1.5	16.1	10.7
8/20/2019	61.8	51.5	0.3	19.3	77.4
8/27/2019	62.0	70.8	0.2	19.3	77.4
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

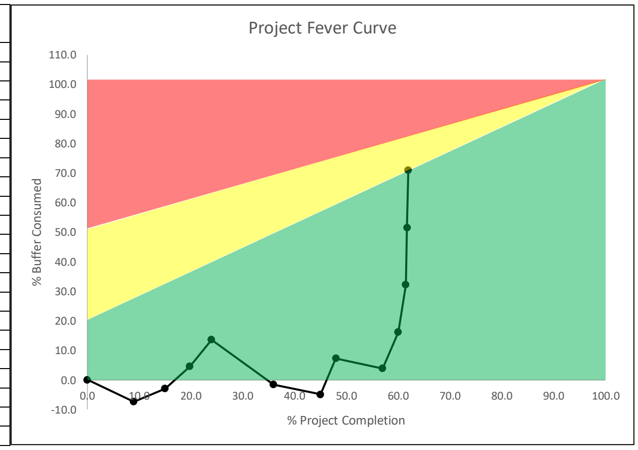


Figure 17. Project Fever Curve 8/27/2019.

Table 10

Task to Project Status and Completion vs Consumption – Delta PV and Mample making.

CC Duration 65 Days Project Buffer Duration 25 Days			
Timeline	8/13/2019	8/20/2019	8/27/2019
CC Duration - Actual (Percentage)	38.5	38.3	38.0
% Job Complete (X)	61.5	61.8	62.0
% Buffer Consumed (Y)	32.15	51.49	70.83
Complete Project Target Percentage	73.88	81.57	89.27
Sample / DPV Parts - 3% of Project (Actual)	61.50	61.75	62.00
Task Percentage Complete	50.00	58.00	66.00

Note. Meeting 8/27/2019 calculations.

Week Twelve 8/29/2019 Meeting

The second meeting for week twelve occurred after the delta PV build and sample build had completed on 8/29/2019. As noted in Figure 18 and Table 11, the buffer consumption did increase to 76.2% and project completion sat at 63%, but the sample and delta parts build was finally able to complete. There was also a noticeable reduction to 5.4 for the BBI. The project completion to buffer consumption did move further into the area of concern (yellow), but this affect was already felt due to the delay in the drawing and BOM release.

During sample and delta PV build, the customer was able to witness the additional manufacturing line producing finished goods (original scope). In addition, the inflators were produced with the component change and new angle tolerance as required. There was no negative feedback during the build, only an emphasis for a quick turnaround on the delta PV testing, as it now served a dual purpose. This point was of great importance to technical engineering as evident from the multiple parties.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019	60.0	16.1	3.0	12.2	4.1
8/13/2019	61.5	32.1	1.5	16.1	10.7
8/20/2019	61.8	51.5	0.3	19.3	77.4
8/27/2019	62.0	70.8	0.2	19.3	77.4
8/29/2019	63.0	76.2	1.0	5.4	5.4
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

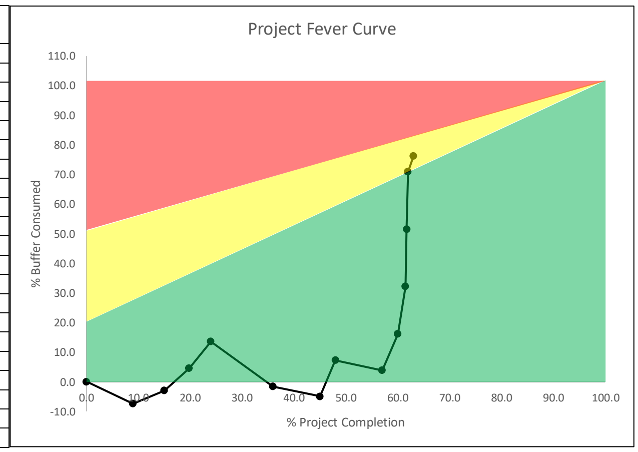


Figure 18. Project Fever Curve 8/29/2019.

Table 11

Task to Project Status and Completion vs Consumption – Delta PV and Sample Making.

CC Duration 65 Days Project Buffer Duration 25 Days				
Timeline	8/13/2019	8/20/2019	8/27/2019	8/29/2016
CC Duration - Actual (Percentage)	38.5	38.3	38.0	37.0
% Job Complete (X)	61.5	61.8	62.0	63.0
% Buffer Consumed (Y)	32.15	51.49	70.83	76.23
Complete Project Target Percentage	73.88	81.57	89.27	92.35
Sample / DPV Parts - 3% of Project (Actual)	61.50	61.75	62.00	63.00
Task Percentage Complete	50.00	58.00	66.00	100.00

Note. Meeting 8/29/2019 calculations.

Additionally, the non-critical chain tasks were officially kicked off since parts were now available to begin the measurement studies. As shown in Section 2 of Appendix C, this chain had 12 days to complete with a 4-day feeding buffer. This table series was used to track the feeding buffer consumption. Unless a concern point arose or the feeding buffer was overconsumed, the critical chain would only affect the Project Fever Curve graph series. The three tasks were combined as a series similar to the critical chain tasks as a means of calculating the feeding buffer into the critical chain.

Week Thirteen and Fourteen

The technical engineer was able to reclaim significant buffer while pushing project completion during week thirteen. As noted in Table 12, one third of testing had completed at this point. Figure 19 displays the fever curve moving out of the area concern (yellow) and further down while putting the project at 70.3% completion. The BBI also registered negative for the first time since July 30th, 2019. In addition, the prelaunch specialists were able to complete the measurement studies ahead of schedule. The non-critical tasks were now at 50% completion and -63% buffer consumption. This allowed the document updates and customer specifics resources to start completion. Calculation tables are displayed in Section 2 of Appendix C.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019	60.0	16.1	3.0	12.2	4.1
8/13/2019	61.5	32.1	1.5	16.1	10.7
8/20/2019	61.8	51.5	0.3	19.3	77.4
8/27/2019	62.0	70.8	0.2	19.3	77.4
8/29/2019	63.0	76.2	1.0	5.4	5.4
9/3/2019	70.3	65.4	7.3	-10.9	-1.5
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

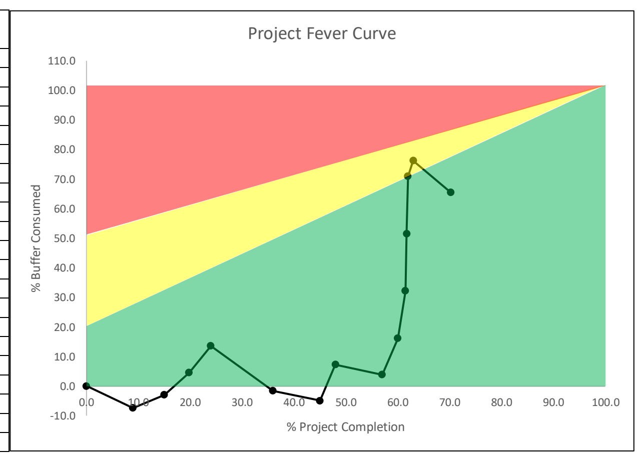


Figure 19. Project Fever Curve 9/3/2019.

Table 12

Task to Project Status and Completion vs Consumption – Delta PV Testing.

CC Duration 65 Days Project Buffer Duration 25 Days	
Timeline	9/3/2019
CC Duration - Actual (Percentage)	29.7
% Job Complete (X)	70.3
% Buffer Consumed (Y)	65.36
Complete Project Target Percentage	95.43
DPV Testing - 22% of Project (Actual)	70.26
Task Percentage Complete	33.00

Note. Meeting 9/3/2019 calculations.

During week fourteen, project progression continued at an increased level. Though Figure 20 shows an increase in buffer consumption, it is minimal at 1.1% more than the previous week. As shown in Table 13, the technical engineer managed to complete another third of the critical chain task at 66% completion for the critical chain. During the September 10th meeting, the technical engineer noted that target completion was set for our next meeting date pending any unforeseen issues.

The non-critical task series also remained on track for week fourteen. The task completion as related to the series was at 84% complete. In addition, the buffer consumption percentage was still negative confirming project progression was ahead of schedule for non-critical tasks. Calculations for the non-critical tasks are displayed in Section 2 of Appendix c.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019	60.0	16.1	3.0	12.2	4.1
8/13/2019	61.5	32.1	1.5	16.1	10.7
8/20/2019	61.8	51.5	0.3	19.3	77.4
8/27/2019	62.0	70.8	0.2	19.3	77.4
8/29/2019	63.0	76.2	1.0	5.4	5.4
9/3/2019	70.3	65.4	7.3	-10.9	-1.5
9/10/2019	77.5	66.5	7.3	1.1	0.2
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

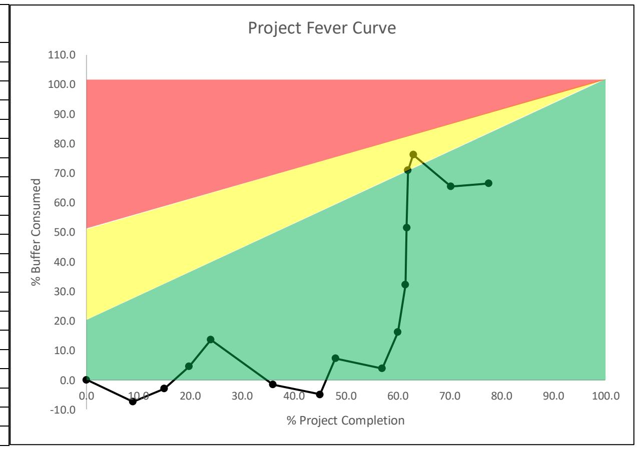


Figure 20. Project Fever Curve 9/10/2019.

Table 13

Task to Project Status and Completion vs Consumption – Delta PV Testing.

CC Duration 65 Days Project Buffer Duration 25 Days		
Timeline	9/3/2019	9/10/2019
CC Duration - Actual (Percentage)	29.7	22.5
% Job Complete (X)	70.3	77.5
% Buffer Consumed (Y)	65.36	66.49
Complete Project Target Percentage	95.43	103.12
DPV Testing - 22% of Project (Actual)	70.26	77.52
Task Percentage Complete	33.00	66.00

Note. Project target exceeds 100% for purpose of scheduled buffer use and calculation. Meeting 9/10/2019 calculations.

Week Fifteen

The delta PV testing was completed on the initial week fifteen meeting. When reviewing Table 14, 100% of the testing completed translated to overall project completion of 85%. Though buffer was consumed as shown in Figure 21, the amount was insignificant at less than a percentage point. The fever curve in turn trended further right toward completion away from the yellow zone of moderate concern. The non-critical chain tasks also completed during September 17th (visible in Section 2 of Appendix C). These items were now ready for final PPAP review and submission. The technical engineer began work on the delta PV report immediately following the weekly status meeting.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019	60.0	16.1	3.0	12.2	4.1
8/13/2019	61.5	32.1	1.5	16.1	10.7
8/20/2019	61.8	51.5	0.3	19.3	77.4
8/27/2019	62.0	70.8	0.2	19.3	77.4
8/29/2019	63.0	76.2	1.0	5.4	5.4
9/3/2019	70.3	65.4	7.3	-10.9	-1.5
9/10/2019	77.5	66.5	7.3	1.1	0.2
9/17/2019	85.0	67.1	7.5	0.6	0.1
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					

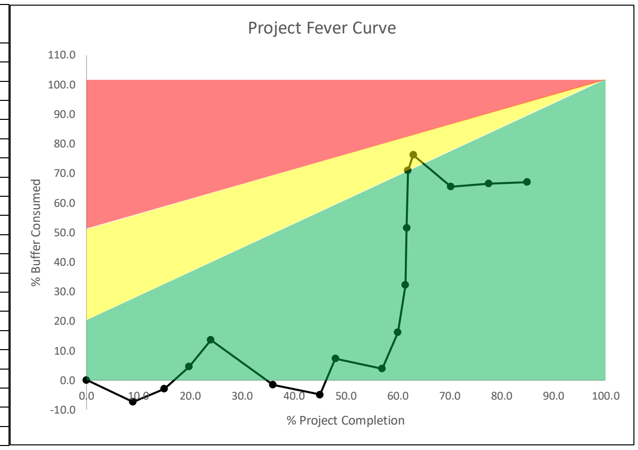


Figure 21. Project Fever Curve 9/17/2019.

Table 14

Task to Project Status and Completion vs Consumption – Delta PV Testing.

CC Duration 65 Days Project Buffer Duration 25 Days			
Timeline	9/3/2019	9/10/2019	9/17/2019
CC Duration - Actual (Percentage)	29.7	22.5	15.0
% Job Complete (X)	70.3	77.5	85.0
% Buffer Consumed (Y)	65.36	66.49	67.05
Complete Project Target Percentage	95.43	103.12	110.82
DPV Testing - 22% of Project (Actual)	70.26	77.52	85.00
Task Percentage Complete	33.00	66.00	100.00

Note. Project target exceeds 100% for purpose of scheduled buffer use and calculation. Meeting 9/17/2019 calculations.

After the September 17th meeting in week fifteen, a follow up meeting was scheduled for the 19th. The technical engineer discussed possible completion by this time during the week fifteen meeting. The PV report was reviewed, and all edits were completed with report signoff in the meeting. As seen in Figure 22, this allowed for more buffer to be reclaimed with a -1.0 BBI yield and downward trending fever curve. The overall project percentage was at 90% complete as shown in Table 15 with a 62.1% buffer consumption.

The final task in the critical chain was to review and complete PPAP for customer submission. The program coordinator was responsible for this task. Immediate organization and review started after the meeting to support timely submission.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019	60.0	16.1	3.0	12.2	4.1
8/13/2019	61.5	32.1	1.5	16.1	10.7
8/20/2019	61.8	51.5	0.3	19.3	77.4
8/27/2019	62.0	70.8	0.2	19.3	77.4
8/29/2019	63.0	76.2	1.0	5.4	5.4
9/3/2019	70.3	65.4	7.3	-10.9	-1.5
9/10/2019	77.5	66.5	7.3	1.1	0.2
9/17/2019	85.0	67.1	7.5	0.6	0.1
9/19/2019	90.0	62.1	5.0	-5.0	-1.0
9/24/2019					
10/1/2019					
10/8/2019					

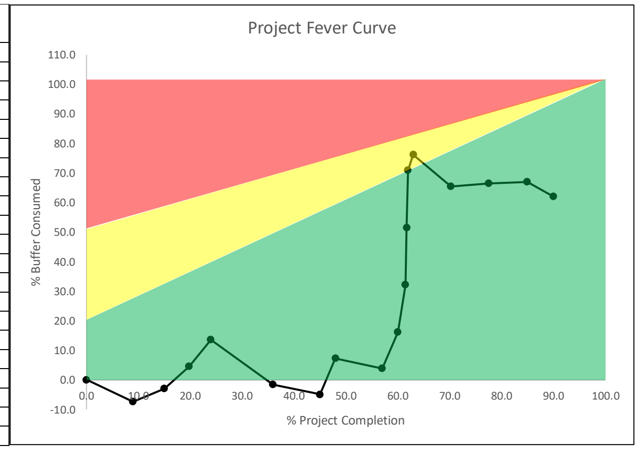


Figure 22. Project Fever Curve 9/19/2019.

Table 15

Task to Project Status and Completion vs Consumption – Delta PV Report.

CC Duration 65 Days Project Buffer Duration 25 Days	
Timeline	9/19/2019
CC Duration - Actual (Percentage)	10.0
% Job Complete (X)	90.0
% Buffer Consumed (Y)	62.08
Complete Project Target Percentage	113.90
DPV Report - 5% of Project (Actual)	90.00
Task Percentage Complete	100.00

Note. Project target exceeds 100% for purpose of scheduled buffer use and calculation. Meeting 9/17/2019 calculations.

Week Sixteen

During the week sixteen meeting on September 24th, the program coordinator confirmed the critical chain task was complete pending final review of PPAP. After the final meeting and minor edits and corrections via review with program management, the PPAP was submitted on 9/24/2019. This submission was ahead of the 10/11/2019 originally scheduled drop date. As shown below in Figure 23 and Table 16, the fever curve continued its downward trend due to quick task completion at -1.4 on the BBI. At the end of the project, 48.1% of the buffer had been consumed.

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019	60.0	16.1	3.0	12.2	4.1
8/13/2019	61.5	32.1	1.5	16.1	10.7
8/20/2019	61.8	51.5	0.3	19.3	77.4
8/27/2019	62.0	70.8	0.2	19.3	77.4
8/29/2019	63.0	76.2	1.0	5.4	5.4
9/3/2019	70.3	65.4	7.3	-10.9	-1.5
9/10/2019	77.5	66.5	7.3	1.1	0.2
9/17/2019	85.0	67.1	7.5	0.6	0.1
9/19/2019	90.0	62.1	5.0	-5.0	-1.0
9/24/2019	100.0	48.1	10.0	-14.0	-1.4
10/1/2019					
10/8/2019					

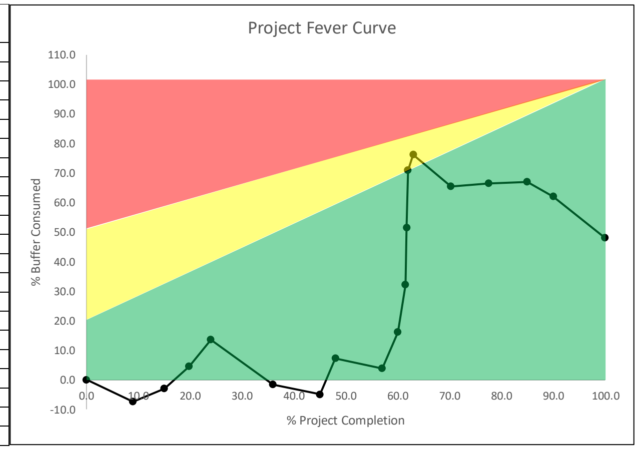


Figure 23. Project Fever Curve 9/24/2019.

Table 16

Task to Project Status and Completion vs Consumption – Organize, Review, and Submit PPAP.

CC Duration 65 Days Project Buffer Duration 25 Days	
Timeline	9/24/2019
CC Duration - Actual (Percentage)	0.0
% Job Complete (X)	100.0
% Buffer Consumed (Y)	48.08
Complete Project Target Percentage	118.51
Complete/Review/Submit PPAP - 10% of Project (Actual)	100
Task Percentage Complete	100.00

Note. The section is highlighted purple to coincide with the WBS departmental coding. Project target exceeds 100% for purpose of scheduled buffer use and calculation. Meeting 9/17/2019 calculations.

Conclusion

By reviewing the quantitative data gathered during the additional line PPAP project using CCPM, the researcher was able to assess the accuracy of this project management discipline. The judgment was based on the completion of the DSSA PPAP process and timely submission to the customer. The expectations, variables, and assumptions weighed heavily on the assessment.

As a new way to combat problems inherent to past projects at DSSA, the use of the CCPM approach in this project proved successful. At a minimum, the need to find a method counter to that of CPM for projects at DSSA has been a success. The CCPM approach allowed for the timely submission of a PPAP to the customer prior to the buffer required end date.

Even though an assumption placed a high strain on the chance of overall project success, the timeline for submission was still met. The top-level drawing and BOM update as requested by the customer and DSSA design was in direct conflict with the seventh assumption identified prior. This obstruction caused a significant amount of lost time to the project. The sample and delta PV build were originally scheduled for Friday August 2nd down the subline process and Monday August 5th for mainline (finished goods).

Once an inflator is through the subline process, it is roughly 70% complete and only waiting on energetics, crimping, and a retention clip. In order to validate a subassembly is holding gas (what inflates airbag), it goes through a 48hour hold process to verify pre and post gas weight. For the original schedule, it was important to complete the subline process on a Friday so the 48hour delay did not affect working hours

(Monday through Friday). Final inspection for mainline occurred immediately once inflator was complete so there was not a need for weekend downtime.

Unfortunately, the two-day completion target warped into roughly a three-week delay after everything in this critical chain task had completed. This was further affected by the customer wanting to be present during the mainline build on August 29th. As noted above, when the sample and delta PV build had completed, the buffer sat at 76.23% consumed. At this point in the project, the researcher had high concerns for overall success until the technical engineer was able to vastly increase project completion percentage.

In addition to the evaluation of CCPM for this project, the use of the status tracking metrics was highly beneficial to on time completion success. The project fever curve allowed the program coordinator and management to not only see project completion percentages, but buffer consumption as well. The separation of areas on the graph by color code was a quick and clear indicator if the project status needed support. In addition, the BBI was a quick indicator if management needed to be concerned.

The overall ability of CCPM to organize and complete tasks along the critical chain proved to be a success. By reviewing the above data, there are obvious points of concern identified throughout the project but there are also times of significant recovery. The distractions and negative effects of multitasking can easily seep into any project as discussed in the literature review. After the week 4 (7/2) meeting updates, the buffer was 13.6% consumed. The program coordinator noticed an upward trend from the prior weeks after reviewing the data (6/18 was at -3% consumed, 6/25 was at 4.5% consumed). Resources had to be corrected to stay on current task and supplier development's project was pushed out to keep the multitasking issue away from the additional line project. As witnessed during week 5 (7/9), resources where able to regain lost ground and the buffer calculated at -1.6% consumed after the correction.

The visual benefit of the project fever curve and the quick summation of the BBI data during weekly reviews allowed for easy and quick identification of project concerns. During 8/6 through 8/29, the project fever curve quickly approached and then entered the yellow area of moderate concern. In addition, the BBI showed its highest values during this sequence. Its was obvious throughout these dates, not only to the project coordinator but management as well, that the project was in jeopardy of missing the completion date. In this project, the drawing updates had to be approved and released from Japan prior to manufacturing. Though DSSA management applied constant pressure for drawing release from Japan, it took several weeks to complete. The success during this time period is the correction interpretation of the project fever curve and BBI by all members.

As noted in the literature review, the organization of the CCPM forced resources to abandon the student syndrome and work diligently to complete tasks. This point is especially evident between weeks 12 (8/29) and 13 (9/3). On week 12, the buffer sat at 76.23% consumed but on week 13 the buffer had been reduced to 65.36%. As resources witnessed the approach of the September 6th due date, task completion percentage increased allowing the buffer date of October 11th for PPAP submission to be compressed. By September 24th, 2019, the additional line PPAP project sat at 100% completion with buffer a consumption of 48.1%.

Future Research and Discussion

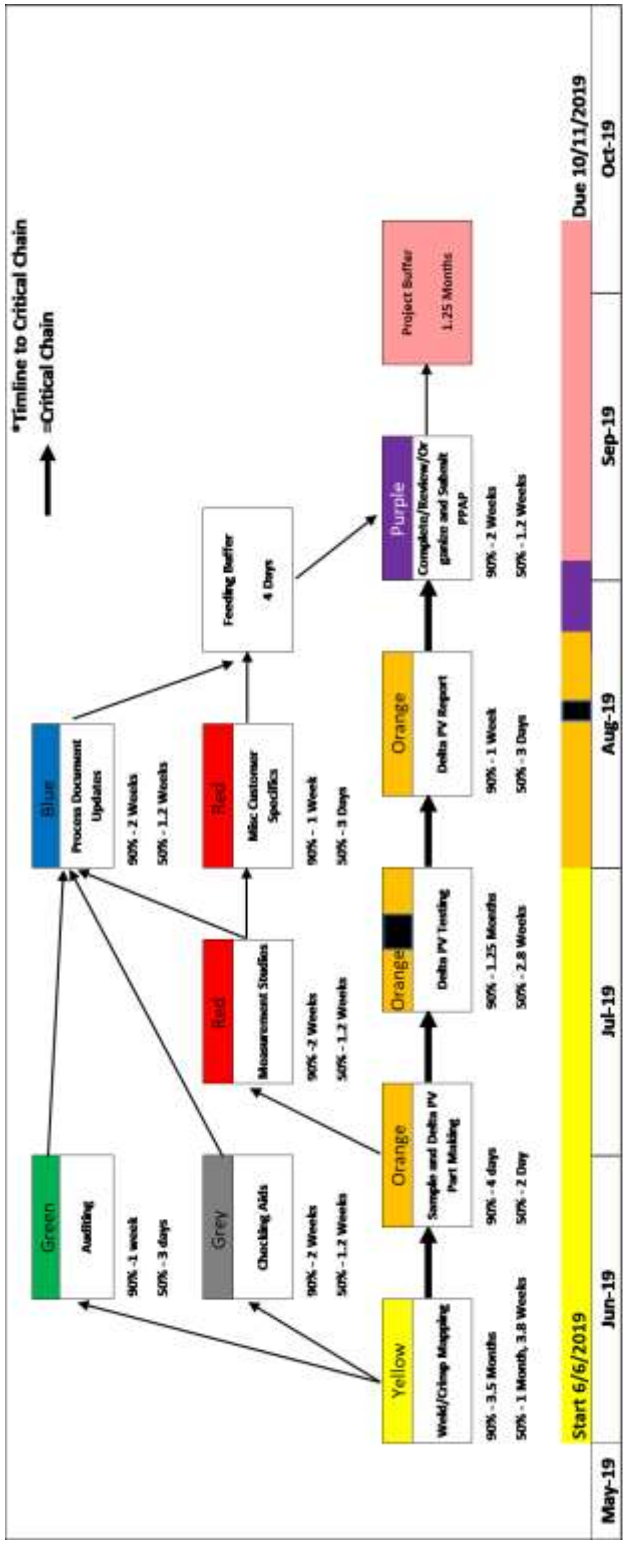
Though a PPAP submission may seem a standard feat, there are many variables in the world of manufacturing outside of planned task completions. This concept became very apparent early in the project. To test the strength and ability of CCPM to complete projects on time, a larger or earlier stage project would help to shed further light on CCPM success as a project management discipline.

Additional projects at DSSA could focus on new inflators with designs unique to current manufacturing. This step would further broaden timelines and factor in higher variables such as line design, inflator life cycle testing, and cycle time studies. Evaluation at this end of the scale would address higher level risk scenarios and variables as well as an increased timeline for buffer sizing studies.

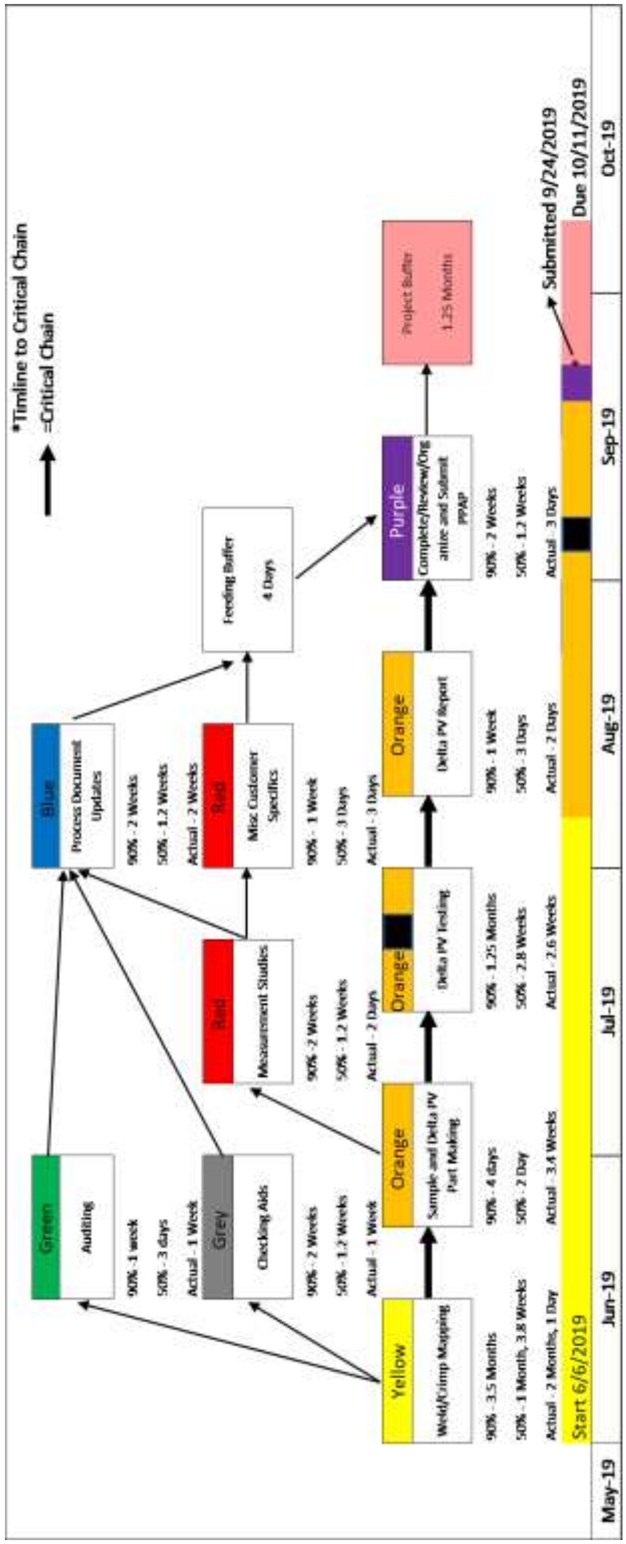
On the opposite end of the spectrum, more minor tasks such as those within the critical chain and non-critical tasks could be studied. During the project, progression on a task as a whole was studied or monitored but not the individual subtasks. For instance, during the weld and crimp critical chain task there are multiple components that must be welded and crimped in order to assemble the inflator. In addition, each weld and crimp must go through a full mapping process with destructive testing that assess capability within a set zone. The BBI would be a highly capable metric in this scenario. If CCPM could be layered throughout the organization from top to bottom, it would offer a view into its true capability.

Appendix A – Work Breakdown Structures and Task Times

Section 1 – Planned WBS with Timeline



Section 2 – Actual WBS with Timeline



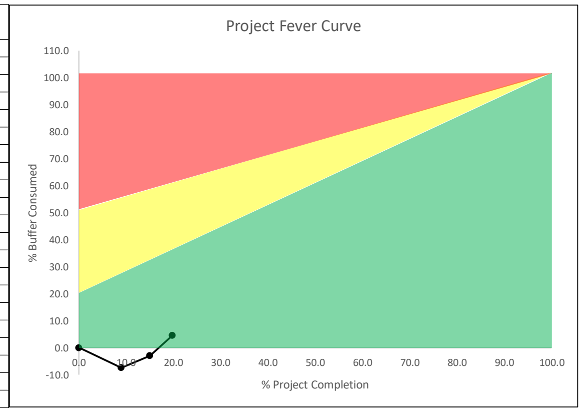
Section 3 – Actual Versus Planned Start and End Times

Task Description	CC	Current Start	Current End	Planed Start	Planed End
Weld & Crimp Maps	CC	6/6/2019	8/6/2019	6/6/2019	8/1/2019
Checking Aids		8/7/2019	8/13/2019	8/2/2019	8/9/2019
Line Auditing		8/7/2019	8/13/2019	8/2/2019	8/6/2019
Delta PV and Sample Making	CC	8/7/2019	8/29/2019	8/2/2019	8/5/2019
Measurement Studies		8/30/2019	9/3/2019	8/6/2019	8/13/2019
Delta PV Testing	CC	8/30/2019	9/17/2019	8/6/2019	8/23/2019
Process Document Updates		9/4/2019	9/17/2019	8/14/2019	8/21/2019
Customer Specifics		9/4/2019	9/6/2019	8/14/2019	8/16/2019
Delta PV Report	CC	9/18/2019	9/19/2010	8/26/2019	8/28/2019
Organize, Review and Submit PPAP Package	CC	9/20/2019	9/24/2019	8/29/2019	9/6/2019

Appendix B – Weekly Figures and Tables Not Shown in Findings

Section 1 – Week 3

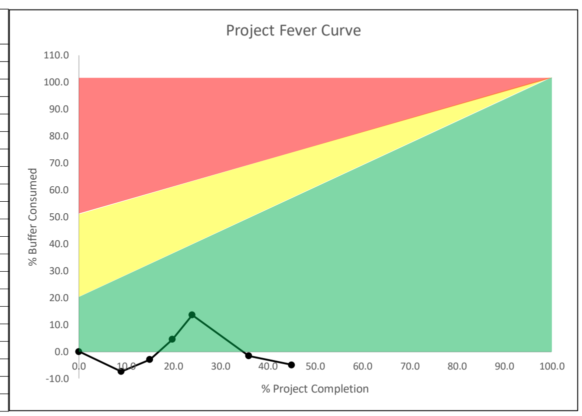
Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019					
7/9/2019					
7/16/2019					
7/23/2019					
7/30/2019					
8/6/2019					
8/13/2019					
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					



CC Duration 65 Days Project Buffer Duration 25 Days			
Timeline	6/11/2019	6/18/2019	6/25/2019
CC Duration - Actual (Percentage)	91.0	85.0	80.2
% Job Complete (X)	9.0	15.0	19.8
% Buffer Consumed (Y)	-7.39	-2.98	4.54
Complete Project Target Percentage	6.16	13.85	21.55
Weld/Crimp - 60% of Project (Actual)	9.00	15.00	19.80
Task Percentage Complete	15.00	25.00	33.00

Section 2 – Week 6

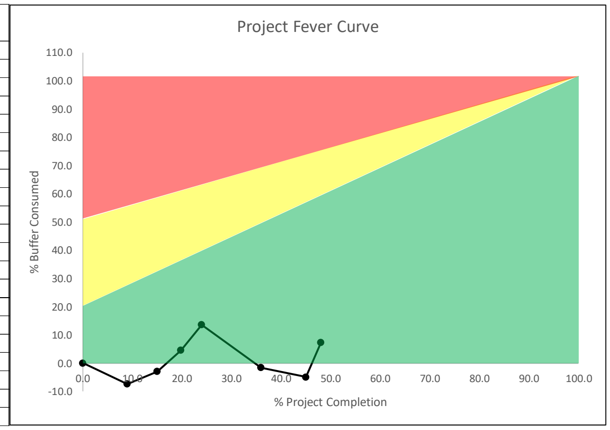
Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019					
7/30/2019					
8/6/2019					
8/13/2019					
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					



CC Duration 65 Days Project Buffer Duration 25 Days						
Timeline	6/11/2019	6/18/2019	6/25/2019	7/2/2019	7/9/2019	7/16/2019
CC Duration - Actual (Percentage)	91.0	85.0	80.2	76.0	64.0	55.0
% Job Complete (X)	9.0	15.0	19.8	24.0	36.0	45.0
% Buffer Consumed (Y)	-7.39	-2.98	4.54	13.61	-1.57	-4.95
Complete Project Target Percentage	6.16	13.85	21.55	29.24	35.40	43.09
Weld/Crimp - 60% of Project (Actual)	9.00	15.00	19.80	24.00	36.00	45.00
Task Percentage Complete	15.00	25.00	33.00	40.00	60.00	75.00

Section 3 – Week 7

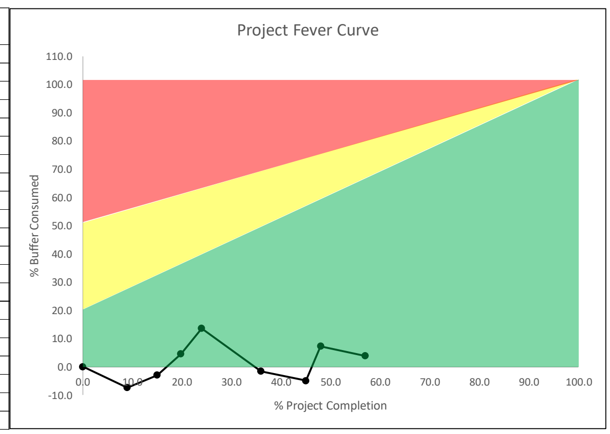
Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019					
8/6/2019					
8/13/2019					
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					



CC Duration 65 Days							
Project Buffer Duration 25 Days							
Timeline	6/11/2019	6/18/2019	6/25/2019	7/2/2019	7/9/2019	7/16/2019	7/23/2019
CC Duration - Actual (Percentage)	91.0	85.0	80.2	76.0	64.0	55.0	52.0
% Job Complete (X)	9.0	15.0	19.8	24.0	36.0	45.0	48.0
% Buffer Consumed (Y)	-7.39	-2.98	4.54	13.61	-1.57	-4.95	7.24
Complete Project Target Percentage	6.16	13.85	21.55	29.24	35.40	43.09	50.79
Weld/Crimp - 60% of Project (Actual)	9.00	15.00	19.80	24.00	36.00	45.00	48.00
Task Percentage Complete	15.00	25.00	33.00	40.00	60.00	75.00	80.00

Section 4 – Week 8

Week	% Project Completion	% Buffer Consumed	Change in Project %	Change in Buffer %	BBI
0	0.0	0.0	0.0	0.0	0.0
6/11/2019	9.0	-7.4	9.0	-7.4	-0.8
6/18/2019	15.0	-3.0	6.0	4.4	0.7
6/25/2019	19.8	4.5	4.8	7.5	1.6
7/2/2019	24.0	13.6	4.2	9.1	2.2
7/9/2019	36.0	-1.6	12.0	-15.2	-1.3
7/16/2019	45.0	-5.0	9.0	-3.4	-0.4
7/23/2019	48.0	7.2	3.0	12.2	4.1
7/30/2019	57.0	3.9	9.0	-3.4	-0.4
8/6/2019					
8/13/2019					
8/20/2019					
8/27/2019					
8/29/2019					
9/3/2019					
9/10/2019					
9/17/2019					
9/19/2019					
9/24/2019					
10/1/2019					
10/8/2019					



CC Duration 65 Days								
Project Buffer Duration 25 Days								
Timeline	6/11/2019	6/18/2019	6/25/2019	7/2/2019	7/9/2019	7/16/2019	7/23/2019	7/30/2019
CC Duration - Actual (Percentage)	91.0	85.0	80.2	76.0	64.0	55.0	52.0	43.0
% Job Complete (X)	9.0	15.0	19.8	24.0	36.0	45.0	48.0	57.0
% Buffer Consumed (Y)	-7.39	-2.98	4.54	13.61	-1.57	-4.95	7.24	3.86
Complete Project Target Percentage	6.16	13.85	21.55	29.24	35.40	43.09	50.79	58.49
Weld/Crimp - 60% of Project (Actual)	9.00	15.00	19.80	24.00	36.00	45.00	48.00	57.00
Task Percentage Complete	15.00	25.00	33.00	40.00	60.00	75.00	80.00	95.00

Appendix C – Full Non-Critical Chain Task Calculations

Section 1 – Checking Aids and Auditing

Non CC Duration 12 Days Feeding Buffer Duration 4 Days		
Timeline	8/6/2019	8/13/2019
Task Duration - Actual (Percentage)	100.0	0.0
% Job Complete (X)	0.0	100.0
% Buffer Consumed (Y)	-	-
Target	0.00	83.00
Checking Aids / Auditing 100%	0.00	100.00

Section 2 – Measurement Studies, Document Updates, and Customer Specifics

Non CC Duration 12 Days Feeding Buffer Duration 4 Days				
Timeline	8/29/2016	9/3/2019	9/10/2019	9/17/2019
CC Duration - Actual (Percentage)	100.0	50.0	16.0	0.0
% Job Complete (X)	0.0	50.0	84.0	100.0
% Buffer Consumed (Y)	0.0	-63.0	-57.0	0.0
Target	0.0	29.0	65.0	100.0
Measurement Studies 50% of Non CC Project (Actual)	0.0	50.0		
Document Updates 33% of Non CC Project (Actual) Customer Specifics 17% of Non CC Project (Actual)			84.0	100.0

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